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UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF ENTOMOLOGY

FOREST INSECT INVESTIGATIONS

THE FIR ENGRAVER BEETLE AND ASSOCIATED INSECTS IN WHITE FIR

SEASON OF 1930

PRELIMINARY REPORT

by

GEORGE R. STRUBLE
Assistant Entomologist

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Summary

An increase in the volume of white fir killed by insects during the past five years has been noticeable in virgin stands, cutover areas and summer-home districts of the central Sierra Nevada region. The first detailed study of damage was made in 1929 on three plots covering 45 acres, established by the California Forest Experiment Station on the Stanislaus National Forest. During the season of 1930 further studies of the injury and experimental work to determine the primary cause, life history and habits of the insects involved were initiated at the Stanislaus branch of the California Forest Experiment Station.

I Primary Insect Involved

1. Scolytus ventralis Lec. is considered mainly responsible for the present widespread losses in white fir.

Analyses of the boles of 38 selected trees representing white fir losses show that this insect is responsible for initial attacks in practically all cases. This attack usually occurs first in the upper bole, and is later supplemented by that of a cerambycid (Tetropium abietis Fall) in the lower bole. Where the more severe infestations occur, Scolytus ventralis Lec. alone kills entire groups of pole-size trees.

2. Tetropium abietis Fall and Scolytus praeceps Lec. are responsible for initial killing in very few instances.

II. Character of Damage. A study of the losses on ten plots and check areas, approximating 450 acres, shows the following types of damage:

1. Top-killing of trees, with S. ventralis primarily responsible. Approximately 3 per cent of trees on remaining stand affected on cutover areas, and 17 per cent of total number of trees on virgin stands affected;

2. Entire killing of single trees or groups of vigorous growing trees of pole size or larger by infestations of S. ventralis. Approximately 7 per cent of volume and 4.5 per cent of trees affected on cutover areas from 1922 to 1930 (represented by Plots MC-8 and MC-5 of C.F.E.S.) and approximately 3.5 per cent of volume and 1% per cent of trees affected on young virgin stands (represented by South Fork Plot).

3. Entire killing of mature or nearly mature trees with upper portion of bole affected by S. ventralis and lower portion by T. abietis. Approximately 1.6 to 2 per cent of total volume and 5 per cent of total number of trees affected on virgin stands since 1927 (represented by Plot 12--typical of light infestation).

4. Partial killing of cambium by scattered attacks of S. ventralis Lec. These occur in patches on upper bole which usually heal over, but severely weaken trees and make them susceptible to rot fungi. This type of damage is common, but impossible to estimate.

III. Life history of Scolytus ventralis Lec. Studies conducted during the 1939 season show that:

1. One generation per year is the rule;

2. New attacks are made by adults which emerge in May and June from overwintering broods of larvae. Attacks average four per square foot in trees that are killed;

3. Egg galleries averaging 8 inches in length are cut transversely in the cambium of living trees and freshly-felled logs. Eggs are deposited from June 15 to September 6 and vary from 25 to 45 per inch of egg gallery;

4. Larvae feed during the summer and overwinter in all stages of larval development;

5. Pupation begins the following May, and the adults emerge from the latter part of May to the latter part of August;

6. A small percentage of larvae fail to complete development during the second season after attack, and hibernate through the second winter. These pupate and emerge the third season, completing a biennial generation.

IV. Parasites and Predators

1. The braconid, Cosmolides brunneri, is considered the most important parasite of S. ventralis Lec. larvae. The eggs of this parasite are laid about the time that S. ventralis larvae are half- to full-grown. Pupation of the parasite occurs within the S. ventralis larval skin.

2. A pteromalid, Cerocephalus sp., is a parasite on S.v. of less importance. Very little is known of its life history.

3. The ostomid, Temnochila virescens var. chlorodia Mann., is an important predator of S.v., the larvae of this species accounting for large numbers of S.v. larvae.

4. The elerid predators, Enoclerus lecontei Lec. and E. sphegeus (Fabr.), are both commonly found in infested logs of S.v. E. lecontei adults are frequently attracted to trap logs. The larvae of both species probably account for large numbers of S.v. larvae.

V. Associated Organisms

1. A stain due to a fungus that attacks the cambium is present in practically every case of successful brood development of S.v. This stain starts from the egg gallery near the attack and spreads in advance of larval feeding.

2. Isolation and inoculation of fungus

a. A fungus was isolated by culturing freshly-infected bits of inner bark on sterile agar in petri dishes, using inner white fir bark extract as nutrient. Pure colonies were transferred to agar slants.

b. Several green trees were successfully inoculated from pure plant cultures by first drilling a wound and then inserting the fungus. A spread of the fungus infection from ½ to 1½ inches occurred from each inoculation point (Photo 9).

c. Several green trees drilled by a 3/32-inch drill and not inoculated, healed rapidly over the wounds without further killing around the wounds (Photo 10).

3. Controlled forced attacks of S. ventralis by liberating new adults in cages surrounding the bases of living trees were unsuccessful. Four trees, varying from suppressed to fast-growing, successfully resisted attacks, and in every case from two to three attacks per beetle indicated unfavorable conditions. Scant development of fungus stain with most of the attacks, and no developments with some attacks, also indicated unfavorable conditions for the development of fungus (Photo 6).

4. Studies on the relation between S.v. attack and fungus stain spread gave the following results:

a. The stain is always present where successful attacks with egg galleries over ½ inch long are made (Photos 5 and 6);

b. Cultures from S.v. adults on agar plates did not result in the presence of the same fungus stain associated with the attack in white fir, but several colonies of other unrelated fungi developed;

c. The percentage of attacks infected with fungus stain on four cages where attacks were forced, varied as follows: Cage #1, 40%; Cage #2, 80%; Cage #3, 92%; Cage #4, 0%;

d. S.v. adults admitted to holes made by a 3/32-inch drill bored for a short distance after they had reached the sapwood. All holes where the beetles bored developed a fungus infection.

VI. Tree Selection by S. ventralis Lec. Studies on groups of trees killed by S.v. during 1929 resulted as follows:

1. Groups killed in heavily-stocked stands, where competition is keen and growth is slow, show very little or no selection on the basis of growth rate;

2. Groups killed in second-growth, moderate to fast-growing stands, show a definite selection for trees of slower growth rate (Photos 11 and 12).

THE FIR ENGRAVER BEETLE AND ASSOCIATED INSECTS IN WHITE FIR, SEASON OF 1930

PRELIMINARY REPORT

Introduction

A survey of insect damage in stands of timber on M.C. Plots 9, 10 and 11 of the California Forest Experiment Station by Miller[1] in 1929 resulted in the discovery of far greater losses due to the fir engraver beetle than to any other forest insect in this type. Since the losses in white fir for the past five years, as represented on these areas and on recreational centers in the Sierra Nevada Mountains, were apparently becoming a somewhat serious economic problem, a project was started to determine the extent to which insects contributed to this situation.

The Stanislaus Branch of the California Forest Experiment Station, located near Strawberry,,was chosen as an appropriate center for experimental studies, which were begun during the summer of 1930 by the writer, assisted by F.C. Johnson of Oregon State College. Experimental areas in this vicinity were located in both pure and mixed stands of white fir, in virgin, cutover and second-growth stands of timber, at elevations between 5,000 and 7,000 feet. Observations were also made on red fir (Abies magnifica), since this species is attacked by the same insects that go into white fir. Although red fir is of much less importance the insect problems are about the same as in white fir, except for a more retarded development on account of higher altitudes and lower temperatures.

The work already done has been limited to studies of insect species affecting white fir and some notes on distribution and biology. In Miller's 1929 report the analyses of top-killed trees are given with a classification of crown injuries. Biological studies were made by Bedard during the two summer seasons of 1928 and 1929. Very few detailed investigations have been made, and the conclusions drawn are at present largely a matter of conjecture.

The studies to be described in this report bear chiefly on the most important primary species of insects affecting white fir, viz., the fir engraver beetle--Scolytus (Ecoptogaster) ventralis Lec. Notes were taken on abundance and distribution as well as biology of some of the less important insects, such as the cerambycid, Tetropium abietis Fell, the scolytid, Scolytus praeceps Lec., and the ambrosia beetles, Gnathotrichus sulcatus Lec. and Platypus wilsoni Sw., but these will not be reported upon aside from giving their relationship to this work.

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[1] Miller, J.M.; Forest insect data, M.C. Plots 9,10,11; season of 1930.

Phases of Problem

The experimental studies carried on with the fir engraver beetle were divided into several methods of attack, outlined as follows:

I. Primary Insects. Analysis of stems, in which trees were felled and carefully examined to note species attacking, stage of brood, distribution, abundance and age of attack.

II. Study of Losses in different areas as follows:
1. In recently cutover stands of mixed white-fir-yellow pine-sugar pine type;
2. In pure virgin stands;
3. In old cutover stands of mixed white fir-yellow pine-sugar pine type.

III. Life History Studies.
1. Records from individual trees standing in the field and from logs in rearing cages;
2. Records from trap trees;
3. Controlled or forced attacks of the fir engraver beetle on caged green trees.

IV. Notes on Parasites and Predators

V. Study of an Associated Fungus, involving culture of the fungus in pure form, inoculating green trees, and leaving others as checks.

VI. Study of Group Killings to determine whether trees were selected according to growth rate.

Analysis of Stems

In this study 30 trees were felled and carefully analyzed. These represented fairly well what might be recognized as typical insect-killed trees for stands found at Strawberry and vicinity in the Stanislaus National Forest. Three of these were topkilled only, four were killed during 1928, 25 during 1929, and six during the 1930 summer season. In spite of the number of trees examined, no two of them were found to be infested in exactly the same way, and it is doubtful if such would ever be the case.

As a result of the stem-analysis work in 1930, four types of attacked trees were recognized in which the amount and association of infestation was quite distinct:

Type I. Top-killed trees in all age classes
a. Recent killing (Miller's Class I[a])
b. Old killing: new leaders forming (Miller's Class II); infestation same as (a)

Type II. Trees entirely killed by one season of attack
a. In young age classes
b. In mature age classes

Miller, J.M.; Forest insect data, M.S. Plots 9,10,11,pp.2-4; Plots No.1.

Type III. Trees entirely killed as a result of progressive attacks extending over several seasons (Miller's Classes III and IV)

Type IV. Living trees with patches of cambium killed by partial attacks—often healing.

A - Type I.

This class consisted of top-killed trees as the result of either S. ventralis Lec. alone, or of a combination of S.v. and S. praeceps or Pityophthorus pseudotsugae. The amount of top-killed is not constant, but often one-third or more of the total height of a tree is killed during a single year. Scolytus ventralis is usually responsible for the initial attack in the thin bark of the top, and if S. praeceps comes in it is secondary. The trees in this type of killing may be of any age class; young, second-growth and old trees are attacked, though top-killing is evidently more common in the older, mature trees.

The analyses made on top-killed trees show that Scolytus ventralis was responsible for initial attacks. The following is a summary of two trees examined:

Tree	DBH	Rings in last inch	Ht.	Distribution of Insects
MT-19	18	8	70	0 to 10 ft.; all exposures; green
				10-30 ft.; E, N and W sides; green; S side, S.v., 1929 killing patches in narrow strip
				30-40 ft.; E, N and ½ W side; green; S side, S.v., scattered 1929 attack, advancing around toward W side
				40-50 ft.; S and W sides; S.v., 1926 attack killing patches, partially healed; 1929 attack killing half of trunk; N and E sides green
				50-70 ft.; all exposures; S.v., 1929 attack killing top; scattered 1926 attack killing patches. S. praeceps, few scattered 1929 attacks
Tray 5	34	18	105	0 to 84 ft.; all exposures; green
				84-102 ft.; all exposures; S.v., 1925 attack, killing top
				102-105 ft.; S.v., few 1925 attacks; P. pseudotsugae, 1925 attack

Note: Tree MT-19 is a red fir (Abies magnifica), but since the insects affecting it are the same as those that go into white fir, and the infestations are identical, this tree is used as an example of Type I.

B. Type II

Represented by trees killed entirely during a single season's attack. Trees in this type are divided according to two age classes, in each of which are found different associations of insects.

a. Young, thrifty, second-growth trees of pole size or larger are attacked when S. ventralis becomes built up in epidemic numbers. The attack occurs from base to top in some trees, and in others from base to within 10 or 20 feet of the top, the remainder being attacked by S. praecepa or left green. Frequently from 5 to 10 feet of the base is left green; and rarely large patches along the main trunk are attacked and killed by S. ventralis, the remainder being killed by P. grandis. The trees attacked in this type often occur in groups of from 5 to 10 or more, and thus present much more of an economic problem than any of the other types. Infestations are represented as follows:

Tree #	Dbh	Rings in last inch	Ht.	Distribution of Insects
M-6	30	12	150	0 to 5 ft.; all exposures; green
				5 to 5 ft.; N side; green; E, S and W sides, S.V., heavy 1929 attack, full-grown larvae
				5 to 70 ft.; all exposures; S.V., heavy 1929 attack; larvae N side, and larvae, pupae, adults S side
				90 to 110 ft., all exposures; S.V.--scattered 1929 attack, larvae and pupae; P. grandis--1930 brood of half-grown larvae
				110 to 130 ft.; all exposures; S.V.--very scattered broods, larvae and pupae; patches killed by 1922 attack
M-7	14	7	60	0 to 30 ft.; all exposures; S.V.--heavy attack, full-grown larvae, pupae, new adults
				30 to 45 ft.; all exposures; S.V.--heavy attack, full-grown larvae, pupae, new adults emerging
				45 to 55 ft.; all exposures; S.V.--pupae, new adults, many emerging
				55 to 60 ft.; S.V.--few attacks; S. praecepa, few attacks, emerged
M-8 (?)	18	9	105	0 to 50 ft.; all exposures; S.V.--scattered attack; larvae, pupae, new adults; T. abietis, few galleries
				50 to 105 ft.; all exposures; S.V.--scattered 1929 attack; larvae, pupae, adults, emergence. P.grandis few attacks. P.pseudotsugae--few attacks near top. S.praecepa--heavy attack last 5 ft.; emerging

b. Mature or nearly mature trees of slow growth rate are represented. The bark is usually quite thick in the lower third of the trunk, and often swellings occur along the trunk which are probably the result of a fungus disease. This type of tree is also very apt to show old healed-over scars, caused by earlier S. ventralis attacks in the upper portion of the trunk. The distribution of insects is illustrated by analyses of the following trees (see also Fig. I):

Tree #	DBH	Rings in last inch	Ht.	Distribution of Insects
235-a	16	14	180	0 to 15 ft.; all exposures; I.abietis--heavy 1929 attack, larvae, pupae. P.silvani--new attacks, eggs. D.sulcatus--new attacks
				15-25 ft.; N side; D.ventralis--scat. 1929 work
				E,S and W sides: I.abietis--1929 att., larvae, pupae. P.silvani--new attack
				25-40 ft.; S and W sides, D.ventralis; heavy 1929 attack. N & E sides: D.ventralis--scat.1929 att.; I.abietis--scat. 1929 att.
				40-100 ft.; all exposures; D.ventralis--heavy 1929 attack, larvae, pupae
				100-115 ft.; S side: D.ventralis--1927 att., killing patches; some healing. N side: D.ventralis--scat.1929 att.; I.abietis--scattered attack
				115-117 ft.; all exposures: D.v.--heavy 1929 att.
				117-120 ft.; D.praeceps--1929 attack
1-19	84	11	65	Base to 7': I.abietis--½ full-grown larvae and some pupae
				7-20': D.v.--1929 light att. at 7' becoming more intense at 20' on E, S and W sides; few 1927 on these sides. I.abietis--scat.att. on E,S & W sides P.grandis--few scat.atts.on S, E and W sides;gr.N side
				20-30': D.v.--heavy 1929 att.all sides: few 1927 atts. killing patches. I.a.--scat.att. P.g.--scat. att.
				30-40': D.v.--1929 att. on E, W and N sides: heavy 1927 att.on S side, killing strip 2' long; considerable fungus. I.a.--few attacks E, N & W sides. P.g.--few attacks
				40-45': D.v.--heavy 1929 att.; scat. 1927 att.; P.g.--scat. att.
				45-60': secondary leader at 45': primary top killed by D.v. in 1924. D.v.(secondary leader)heavy att.
				60-65': D.v.--scat.att.; P.g.--heavy att.

c. Type III. Trees which have been killed after several seasons of progressive attack, starting at the top. Classes III and IV, devised by Miller, are included in this type. D.ventralis is responsible for the initial killing of the top, and is often responsible for the death of a considerable portion of the trunk. Attacks of I.abietis are found on the main part of the bole after the tree has been severely weakened. These attacks extend to the base in older infestations, or to within several feet of the base in more recent infestations. An example of this type is summarized below (see also Fig. 1)

Tree	Dbh	Rings in last inch	Ht.	Distribution of Insects
WF-18	28	9	100	Base-30'; all exposures; green: T.S.--scat. att.; few healed scars
			30-35'; N, E and W sides; green: T.S.--scat. old attack; few recent atts. S side: S.V.--1929 att. killing patch 1 ft. wide	
			35-37'; all exposures: green: T.S.--healed-over scars	
			37-45'; S and ½ of W side; S.V.--heavy att.; few old scars of 1926 att. E, N and ½ of W side; green; T.S.--healed-over scars	
			45-60'; S and W sides; S.V.--heavy 1926 att.; old 1926 att. E side, killing patches. N and W sides green: S.V.--few 1929 atts.; T.S.--old scars	
			60-97'; all exposures; S.V.--1926 att.killing top	
			97-100'; P. pseudotsugae	

d. Type IV. Infestations in this type are very difficult to locate in the field, since outward evidence of attacks is very often lacking. The ability of D. ventralis to attack and establish broods by killing out patches on the side of a green tree causes a weakened condition which frequently results in future attacks and death. But often the green areas surrounding the killed patches heal over them and leave a scar buried in the wood. Frequently the dead areas become infected with rot fungi, and severe injury or death results. Because of the extreme difficulty of locating the infested trees, it is practically impossible to estimate the damage in this type without making a stem analysis of all trees in the stand.

Insect Losses in White Fir

The survey of insect damage in white fir outlined in the following pages is based on 8 sample plots of the California Forest Experiment Station and two plots of the Bureau of Entomology. A 100% cruise was made on each of the plots where account was taken of top-killed trees, both old and recent, and trees killed entirely during the 1923, 1929 and 1930 seasons. The amount of loss of top-killed trees is quite indefinite, since it is practically impossible to determine the insect damage for any given year when only a portion of the top is killed back. The greatest tangible losses were attributed to trees killed entirely during 1926, 1929 and 1930, most of which were smaller second-growth white fir.

A. Experiment Station Plots, established by C.F.E.S. The location of the areas included in these surveys is indicated on the map (Fig. 8 . Stand and volume figures were obtained from Dunning's records of the W.C. plots. Since figures were not available for Plot WC-18 or WC-1, the amounts of loss on these two plots shown in the surveys below are based on the original stand figures of Plot WC-5 before logging, which was of similar composition. Calculations of percentage were obtained by using a conversion factor of 4 to change cubic volume to board feet. A summary description of each of the plots and of the losses on each is given as follows:

1. MC Plot 9
   a. Location: NE¼ Sec. 22, T 4 N, R 10 E
   b. Area: 15 acres
   c. Purpose: To study the effect of logging according to Forest Service methods
   d. Logged: 1929
   e. No. trees (M.T.) per acre left: 9.9
   f. Vol. per acre B.F. left: 3,894.7 b.f.
   g. Type: Sugar pine-white fir
   h. Summary of loss:

Type of Loss	Year	No. Trees	Vol.cu.ft.	Estimated % Tot. Trees	Estimated % Tot. Vol.
Ia		1		.7	
III	1930	1	108	.7	1

2. MC Plot 10
   a. Location: Adjoining MC Plot 9 on E side in NE¼ Sec.22, T 4 N, R 10 E
   b. Area: 15 acres
   c. Purpose: To study effect of logging by Mason system
   d. Logged: 1929
   e. No. trees per acre (M.T.) left: 19.4
   f. Vol. per acre (M.T.) left: 25,536.6 b.f.
   g. Type: Sugar pine-white fir
   h. Summary of loss:

Type of Loss	Year	No. Trees	Vol.cu.ft.	Estimated % Tot. Trees	Estimated % Tot. Vol.
Ia		5		1	
Ib		56		12	
IIa	1929	1	179	.3	.1
III	1930	1	682	.3	.8

3. MC Plot 11
   a. Location: Adj. MC Plot 10 on N in parts of Secs. 21 & 22, T4N, R10E
   b. Area: 15 acres
   c. Purpose: To study effect of logging according to system used on private lands
   d. Logged: 1929
   e. Trees left per acre (M.T.): 17.4
   f. Vol. per acre (M.T.) left: 8,670.6
   g. Type: Sugar pine-white fir
   h. Summary of loss:

Type of Loss	Year	No. Trees	Vol.cu.ft.	Estimated % Tot. Trees	Estimated % Tot. Vol.
Ia		3		1.1	
Ib		5		1.9	
IIa	1929	1	60	.3	.1
	1930	2	70	.7	.3

4. MC Plot 12
   a. Location: NE¼ Sec. 4, T 4 N, R 10 E
   b. Area: 5 acres
   c. Purpose: Study of effect of natural influences
   d. Virgin stand
   e. Trees per acre (M.T.): 17.4
   f. Vol. per acre (M.T.) 10,093 bd.ft.
   g. Type: Sugar pine-white fir
   h. Summary of loss:

Type of Loss	Year	No. Trees	Vol.cu.ft.	Estimated % Tot. Trees	Estimated % Tot. Vol.
Ia		2		10.3	
Ib		0			
IIa	1929	2	498	4.2	1
III since 1927		4	1337.4	4.6	1.6

5. MC Plot 6

a. Location: [illegible] of Sec. 29, T 4 N, R 13 E
b. Area: 8.4 acres
c. Purpose: Methods of cutting varied to secure greater sugar pine reproduction in a stand which would normally come in to white fir
d. Logged: 1928
e. Trees per acre (S.F.) left: 20.2
f. Vol. per acre (W.F.) left: 7,282 bd.ft.
g. Type: Sugar pine-white fir
h. Summary of loss:

Type of Loss	Year	No. Trees	Vol.cu.ft.	Estimated % Tot. Trees	Estimated % Tot. Vol.
IIa	1929	4	8,061	2.3	10

6. MC Plot 8

a. Location: in NE of Sec. 6, T 4 N, R 13 E
b. Area: 10 acres
c. Purpose: to study rate of restocking and species coming in on a clean-cut area
d. Logged: 1928
e. Trees per acre (W.F.) left: 7.1
f. Vol. per acre (W.F.) left: 2,598 bd.ft.
g. Type: Sugar pine-white fir-yellow pine
h. Summary of loss:

Type of Loss	Year	No. Trees	Vol.cu.ft.	Estimated % Tot. Trees	Estimated % Tot. Vol.
Ib		2		2.8	
IIa	1927	2	39.6	2.8	.8
	1928	3	39.6	4.2	.4
	1929	3	226.2	4.2	3.0

7. MC Plot 7

a. Location: In parts of NE¼ and SE¼ of Sec. 4 and NE¼ of Sec. 9, T 4 N, R 13 E, occupying a strip 20x80 chains
b. Area: 160 acres
c. Purpose: Slash disposal study of Forest Service
d. Logged: 1928
e. Trees left per acre (S.F.): 8
f. Vol. left per acre (W.F.): 2,595 bd.ft.
g. Type: Sugar pine-white fir yellow pine
h. Summary of loss:

Type of Loss	Year	No. Trees	Vol.cu.ft.	Estimated % Tot. Trees	Estimated % Tot. Vol.
Ia		4		.8	
Ib		7		.8	
IIa	1928	14	630.6	1.7	.4
	1929	24	942.8	3.0	.9
	1930	4	162.8	.5	.1
IIb	1928	6	663	.3	.6
	1929	1	59	.1	.05
III	1928	2	87	.2	.08
	1930	1	1.9	.1	

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*(Note for P.10) Stand and volume figures for Plot 12 approximate: taken from original stand Plot 5 before logging.

B. [illegible] Plot 1

a. Location: Near township line bet. Ts 4 and 5, Nos. 35, T 5 N, R 16 E
b. Area: [illegible] acres
c. Purpose: [illegible]measuration study in white fir, virgin stand
d. Pure virgin white fir
e. Type: Sugar pine-white fir
f. Summary of losses:

Type of loss	Year	No. trees	Vol.cu.ft.	Tot. Trees	Tot. Vol.
Ib		1			
XII	(1919)	1	816	11	82

B. South Fork Check Area. This plot of 40 acres was laid out by Johnson and Struble on August 28, when a cruise of the insect damage was made. It occupies a rather steep northwest slope directly above and parallel to the South Fork of the Stanislaus River, in parts of Secs. 19 and 30, T 4 N, R 18 E (see map, Fig. 10). Beginning at the ¼ corner between Secs. 19 and 30, the boundary lies as follows: 80° N, 40 ch.ins; 40° E, 10 ch.; 80° S, 40 ch.; 40° W, 10 ch. The area consists of almost pure virgin white fir, but is mixed in places with sugar pine. The stand is heavily stocked and is in an even-aged class of about 100 years, with scattered old overmature trees. Parts of the north and east sides of the plot were logged off about five years ago, so that approximately 27 acres are in virgin timber; the remainder is thinned out.

This area was selected to follow the loss on a heavily stocked virgin stand of white fir. The results of competition had already begun to show up in a large group of trees killed during 1929 near the north end. (This group was used in the Water Tank tree selection study.) The difficulty of establishing an area large enough in the same type of stand made it necessary to follow a narrow strip along the northwest slope of the river. The following figures show the loss for this plot:

Type of Loss	No.of Trees	Vol. Cu.Ft.	Year of Loss
Ia	13		
Ib	31		
IIa	35	952.8	1928
	47	2,345.2	1929
	7	892.8	1930
IIb	4	798.9	1928
	5	1,048.0	1929
	1	127.0	1930
XII	1	558.0	1929

C. Cold Springs Check Area. This area is divided into two parts. The first part is composed of 100 acres in light cutover land in yellow pine-sugar pine type, Site II, which was logged by the Standard Lumber Company in 1913. The second part is composed of approximately 80 acres in heavily cutover land in second-growth white fir, logged about 1910 by the Cold Spring Mill. Both areas are included in a triangle formed by the N and W section lines of Sec. 31, T 4 N, R 18 E, and the North Fork of the Tuolumne River. They are separated by a fence line which marks the end of the light cutting and beginning of heavy cutting (see map, Fig. 9).

1. Light cutting plot. This area of about 100 acres was cruised in August 1924 and June 1926 by Person to obtain a loss estimate on cut-over areas. The cruise made in 1930 includes losses in yellow pine, sugar pine and white fir for a three-year period, beginning in 1928. Percentage losses for yellow pine are based on volume and increment figures given in Person's report.* The following figures show losses for each species:

a. Yellow Pine—	Type of Loss	Year	No. Trees	Vol. b.f.	% Tot. Vol	% Ann. Inc.
	Top-killed	1928	4	2,410	.1	13
	" "	1929	8	4,820	.3	25
	Entirely "	1928	8	10,960	.7	89
		1929	7	5,670	.3	30
		1930	2	1,980	.1	10

b. Sugar Pine—	Entirely "	1929	2	690

				Vol. cu. ft.
c. White Fir—	Ia		8	
	Ib		6	
	IIa	1928	1	10.5
		1929	11	694.1
		1930	1	21.0
	IIb	1929	2	721.0
		1930	1	443.0
	III	1930	1	127.5

2. Heavy cutting plot. This plot of about 80 acres, located due south of the light cutting plot, is composed almost entirely of vigorous second-growth white fir, with scattered yellow pine and sugar pine showing up. It slopes principally to the east, with northeast and southeast exposures. Group killings were conspicuous in this area during 1929. The following figures give an estimate of the 1928 and 1929 damage. In spite of the heavy infestation of S. ventralis in this area in 1929, not a single 1930 tree was found at the time the cruise was made.

a. Jeffrey Pine—	Type of Loss	Year	No. Trees	Vol. b.f.
	Ent. killed	1930	1	650

b. Sugar Pine—	" "	1929	2	560

				Vol. cu. ft.
c. White Fir—	Ia		3	
	Ib		2	
	IIa	1928	5	326
		1929	22	732.2
	IIb	1928	1	368.0
	III	1930	1	272.0

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*Person, H.L. Report on Study of Insect Losses on Cutover Areas of District 5; Feb. 20, 1926: P.17.

Life History Studies

Previous records obtained on the life history of S.ventralis indicate that one generation a year is the rule; but since occasional records were taken from trap logs and standing trees, the accuracy of the above conclusions is questioned. Hedard's* observations on a green trap log and notes of the Bureau of Entomology indicate about the same rate of development. According to Hedard, in his 1929 studies, eggs which were laid on July 11 developed to mature larvae by August 20. Since the same brood was still in the larval stage in September, it probably overwintered in this stage of development.

The data on the life history of S.ventralis contained in the following pages were taken between May 17 and September 10. A number of notes were obtained on both the overwintering broods of the 1929 generation and the broods developed from 1930 attacks in green trees and trap logs. As a result of this work the life cycle of the fir engraver beetle is pretty well established. The adult attacks standing green trees between June 15 and September 6, with the heaviest attack period occurring between July 13 and August 15. Attacks are apparently initiated by the female, though this is conjectural; only one male is present in the nuptial chamber after attacks are successfully started, and he remains there until the egg gallery is about two-thirds completed, when he abandons his post. As new attacks are successfully started, a fungus develops which stains the inner bark and sapwood for a short distance in a vertical direction on either side of the egg gallery.

Egg galleries are constructed at right angles to the axis of the tree and attain a length of from 4 to 6½ inches. Eggs are packed in niches on each side of the gallery and vary in number from 35 to 45 per inch. The incubation period is from 10 to 14 days.

The larvae feed at right angles to the egg gallery, constructing channels which groove the inner bark and surface of the sapwood for their entire length. Some develop to maturity before hibernation, and others are in all stages before hibernating for the winter.

Pupation takes place from the outer bark to a short distance in the sapwood, depending on bark thickness. The first pupae occur about May 15, following hibernation, and the first adults appear from 10 to 15 days after the first pupae (see Life History Chart, Fig. 2).

Methods of Obtaining Seasonal History Records

Records from 1929 overwintering trees were taken as follows:

1. By felling trees in group killings that were infested with S.V. at about the same time. Twenty-six trees were felled between June 12 and August 20. Careful examinations were made on the stages of brood at the time of felling the trees.

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*Hedard, W.D. A Preliminary Study of the Coleoptera Attacking White Fir (Abies concolor); M.S. Thesis, Syracuse, N.Y., May 1930.

B. By keeping continuous records on a standing infested tree and on an infested tree felled early in the season. Notes on these trees were taken periodically and a comparative rate of development was obtained.

C. By keeping emergence records on brood bark and brood logs placed in rearing cages. Three types of cages were used: (a) a triangular cage (Photo 2) in which brood logs of S.ventralis were placed; (b) a box cage, open bottom on ground, with a tight-fitting removable top, dimensions 30x30x24 inches high; and (c) screen cylinder cages constructed about 3-foot logs and drawn into a funnel with a small opening at the bottom. The triangular type--10 ft. long by 4 ft. wide by 8 ft. high at the tall end--proved very satisfactory in the western pine beetle studies by Person and was most suitable in these studies. The box cages also were efficient, but too small to be of much service as rearing cages. The screen cylinders suggested by Dr. Craighead were inefficient on account of the difficulty of collecting the insects. Records of emergence period also were obtained by placing bark and brood logs in galvanized iron cylinders 14 in. in diameter by 24 in. high, of the type described by Person* in a 1928 report. The beetles, emerging, dropped into a glass jar below, when counts were made. The cage data on emergence were also supplemented by observations on the felled trees.

Records from 1930 Broods were taken (1) from new attacks made on standing green trees, and (2) from attacks made on green trap logs. Many data were taken on attacks, length of egg gallery, number of eggs, rate of brood development and brood abundance.

Data from 1929 Broods

I. Felled trees infested with S.v. Table 1, which follows, gives a complete summary of the broods found at the time of felling. The largest percentage of larvae were found to be fully mature at the beginning of the summer, some pupating as early as May 24. Many were found to be only one-quarter grown, however, and in some cases less than that. New adults were first noted May 28 and many more were observed after this date, especially during the latter part of June and all of July.

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*Person, H.L. Western Pine Beetle Biological Studies, Stanislaus Nat. Forest, Season of 1928: Berkeley, Calif., June 1, 1929.

Table 1

1929 S. ventralis Broods in Felled Trees

Date	Tree	Larvae			Pupae	New Adults	Emerge
		0-	--	-1			
May 23	Logs on gr.			x			
24	do			x	x		
26	P33a			x	x		
27	Logs on gr.		x	x	x		
28	K-12		x	x	x	x	x
June 8	Misc. log	x					
	Strawberry						
	Group			x	x		
12	K--1			x	x		
16	K--3			x	x		
18	K--5			x	x	x	
19	K--6		x	x			
20	K--7		x	x	x	x	x
23	64-K		x	x	x	x	
	93-K		x	x	x	x	
24	K--9			x	x		
	K-10		x	x	x	x	
25	K-11		x	x	x		
26	K-13			x	x	x	x
	K-15			x	x	x	x
27	K-14			x	x	x	
	139a			x			
July 1	69-K		x	x	x	x	x
	88-K		x	x	x	x	x
9	K-16			x	x	x	x
15	K-17		x	x			
24	MT-18		x	x	x		
26	K-22			x	x	x	
30	K-23			x	x	x	
Aug.15	K-24			x	x	x	x
20	K-26			x			

One of the interesting facts about this study is that larvae from 1928 broods were found in trees felled during the entire summer. Although the majority of the larvae had pupated and emerged by the middle of August, there were still many of them left in the larval stage after September 10. An observation made November 4 by the writer showed 1929 larvae in some of the trees, and these were now unquestionably hibernating for the winter.

2. Continuous records on ~~[illegible]~~ standing and felled trees. Observations on two separate trees containing 1928 broods show interesting follow-up records during the summer of 1930. Tree #19153 Dept.U.S., located at approximately 7,000 feet elevation near the Mono highway on Patterson Grade, was first examined on May 19, when a broad of ½-grown larvae were found. Subsequent observations showed ½-full-grown larvae and pupae June 27; ½-full-grown larvae, pupae, new adults and some emergence July 18; full-grown larvae to emergence August 15; very few larvae and one pupa noted September 4, with most of brood emerged; tree entirely abandoned Nov. 5.

Tree #19154 Dept.U.S., in a 1929 group killing near Strawberry Resort, at an elevation of 5,200 feet, was felled May 19. On this date full-grown larvae were present; larvae, pupae and new adults June 20; larvae to some emergence July 15; larvae to some emergence August 23; larvae September 4, considerable parasitism; larvae and parasite seasons November 4. This tree is fairly typical of the brood in all the trees in the group killings, though conditions may have changed somewhat after felling the tree. Greater pupation and emergence, barring parasitism, would undoubtedly have taken place if the tree were left standing. Other trees in the group, however, also contained a small percentage of larvae after the main emergence period was over.

Although the tree in the Strawberry group was nearly 2,000 ft. lower in elevation than the tree on Patterson Grade, the entire brood in the latter tree completed its development, whereas in the former tree a percentage of the brood remained in the larval stage. Since the brood in the Strawberry tree was further advanced than the Patterson Grade tree at the beginning of the season, it is interesting to note that the entire brood in the Patterson Grade tree developed to maturity more rapidly than the Strawberry tree, in spite of the higher elevation. The fact that the Strawberry tree was felled early in the season and left lying on the ground may have been responsible for a large part of the difference.

3. Emergence data

a. Period of Emergence

Field notes and data from the rearing cages over the summer show a continuous emergence of S.ventralis adults, the earliest ones appearing May 28. The period of greatest emergence and subsequent falling-off in number of adults is shown by Fig. 3, which is a graphic representation of the emergence in the large triangular rearing cage. As indicated by this figure, maximum emergence occurs during the month of July, falls off sharply after the middle of August, and is practically complete soon after the first of September. Fluctuations of maximum temperature for ten-day periods, also shown in Fig. 3, tend to indicate some influence on the rate of emergence.

b. Number of Beetles Emerging

The numbers of beetles which emerged from two of the rearing cages and two of the galvanized cylinders are summarized in Table 2.

Table 2

Emergence Data(1929)Broods in Rearing Cages Between June 19 and Sept.3

Rearing Cage	No.sq.ft. Bark Area	No.S.v. Beetles Emerged	Beetles per sq.ft.	Other Notes
Triangle	186.39	5,763	30.9	Logs pinned in cage
Box	31.47	831	26.0	do
Can #3	10.00	154	15.4	Bark removed from log
" #4	8.00	321	40.2	" left on log

The above results show 30.9 beetles per square foot in the triangular type, compared with 26 per sq.ft. of bark area for the box type. The difference between the emergence in the two types of cages is too slight to be of any significance so far as the rearing cage is concerned, but it is probably due to the difference in amount of brood present in the logs put in each cage.

A comparison of emergence from bark and logs put in the galvanized cans shows a marked difference. Emergence from 10 sq.ft. of bark amounted to 15.4 beetles per sq.ft., and from the log containing 8 sq.ft. of bark area emergence amounted to 40.2 beetles per sq.ft. The difference here is undoubtedly due to drying-out of the bark and subsequent killing of the brood after the bark is removed from the log.

c. Emergence variation in standing trees.

It has been observed that there is a definite periodic difference between the emergence of beetles in the top and those in the basal portion of a tree. Studies made on the trees felled for analysis on different dates during the summer of 1930 show that the variation in emergence between top and base of a given tree may be from two weeks to a month in brood of about the same age. The reasons for variation are primarily due to temperature differences along the trunk, influenced by denser shading and thicker bark in the basal portion, as compared with the less dense and thinner bark of the upper portion.

Data from 1930 Broods

1. Study of Broods in Standing Trees. The difficulty of locating new attacks in the field prevented observation on broods established earliest in the 1930 summer season. One record which is among the first 1930 attacks was observed June 24 in Tree M-9. In it were new S.ventralis adults extending galleries and laying eggs, some of the galleries being 4 to 5 inches in length. Very small larvae were also seen. This tree had been attacked in the lower portion of the trunk by a 1929 brood of S.ventralis, but the top portion was still green and therefore quite attractive to the first beetles in flight. For this reason it is believed that the attack is one of the earliest for the 1930 season.

Other attacks on standing trees in the field were found considerably later than the one on M-9. Brood developments of these attacks are summarized in Table 3, which follows:

Table 3

Summary of 1930 Broods in Standing Trees

Tree	Date	New Attack	Eggs	Larvae 0-	Larvae 1-	Larvae -1	Pupae	New Ad	Emer.
M--1	July 29	x							
M--2	Aug. 1	x	x	x	x				
M--	" 16	x	x	x					
M--4	" 25				x	x	x	x	x
M-63	Sept. 5	x	x	x					
M-66	" 5			x	x				

As shown by the table, most of the broods at the time of observation were found to be in any stage from eggs to ½-grown larvae. The unusually-advanced brood of Tree N-4 is an exception to the rate of development compared with other 1930 attacks, and is therefore open to the question as to whether it is a 1930 brood or a very late 1929 brood. The writer is inclined to think it is a 1930 brood on account of the condition of the bark on the tree, which was still green for a considerable portion of the trunk. Very little emergence had taken place and the largest proportion of brood was still in the larval stage. The fact that the tree was standing in an exposed, open, logged-off site, and that there were few branches and thin foliage to shade the trunk, undoubtedly influenced the greater development of brood by increasing temperatures along the trunk.

E. Study of E.Y. Broods in Trap Trees. Four trap trees were felled in different localities to obtain a record of earliest flight and of brood development. Trap Tree #1, 18 inches d.b.h. and 80 feet high, was felled near the Strawberry group killing on a north slope at an elevation of about 5,200 feet. Tree #2, 16 inches d.b.h. and 80 ft. high, was felled in the Cold Springs area on an east slope at an elevation of about 5,000 feet. Trap Tree #3, 10 inches d.b.h. and 30 feet high, was felled near Patterson Brake on a north slope near the Tioga highway at an elevation of approximately 7,000 feet. Tree #5, 34 in. d.b.h. and 105 ft. high, was located near the Stanislaus branch of the California Forest Experiment Station, elevation 5,140 ft. All traps were felled in the shade and where exposure to the sun would not prevent the logs from being attacked. A study of attacks and subsequent developments of broods in these trees is summarized in Table 4.

Table 4

Study of Brood Development in Trap Trees

Tree #	Date Felled	First Attack	Eggs	Larvae 0-	Larvae ¼	Larvae ½-¾	Larvae ¾-1
1	June 9	June 30	7/ 1-8/ 8	7/14-8/ 5	8/ 8-9/1	9/1-11-4	overwinter
2	" 11	" 30	7/ 8-7/31	7/10-8/14	8/14-9/4	9/4-11/4	overwinter
3	" 13	July 10	7/18-8/15	7/25-8/20	8/20-9/4	9/4-11/5	overwinter
45	July 16	Aug. 1	8/ 4-9/ 5	8/22-9/ 8	9/ 5-11/4		

The rate of development is about the same for all the trees. Eggs hatch within ten days to two weeks following the time they are laid. The egg-laying period is 4 to 6 weeks, and the resulting brood development is correspondingly prolonged. In Trap Trees 1 and 2 the entire brood reached the full-grown larval stage by November 4 and were already hibernating for the winter. The brood in Trap Tree #3 had a small percentage of brood still in the ¾-grown larval stage by November 4, but the largest proportion of brood was full-grown by this time. The brood in Trap Tree #5 developed at about the same rate as the other broods, but reached only the ½-¾-grown larval stage by November 4, since development started over a month later in the summer.

3. Abundance of 1930 Broods. The data obtained on 1930 attacks and broods show a marked difference in amount of brood compared with adults emerging from 1929 broods. Detailed studies were made on Trap Trees 1 and 2 and Tree M-3, which was killed during the summer. Counts on parent adults and brood and notes on length of egg gallery were made by peeling the bark from one-foot logs. Parent adults found at either end of the egg gallery were assumed to be females, and those in the entrance hole or nuptial chamber were assumed to be males. A check-up on these assumptions later by microscopic dissection of genitalia proved them to be correct. Table 5 gives a summary of brood development in Trap Logs 1 and 2 and Tree M-3.

Table 5

Abundance of Broods in First Stages

Tree	Sq. Ft. Bark Area	No. Attacks	Total Length of Gallery-in.	Aver. Length of Gallery-in.	Eggs	Larvae	Total Brood	Brood per Att.	Brood per Sq. Ft.	Att. per Sq. Ft.	F. Adults	
											F	M
Trap 1		70	232.25	3.31	1624	4456	8,080	86.8			65	88
M-3	7.8	80	173.75	3.47	884	1663	2,247	44.9	6.6	298.2	78	50
Trap 2	21.62	67	158.75	2.36	2584	1349	3,936	98.7	3.1	135.7	88	70

Since at the time these data were taken egg-gallery construction and egg-laying were slightly more than half over, the brood is therefore probably much less than it might have been. The average length of egg gallery when completed is about 5 inches. Even though this be true it is seen that the amount of brood started is enormous compared with the number of adults emerging from 1929 broods on a square-foot basis. Unfortunately the bark area on Trap Tree #1 was not obtained, and as a result cannot be used to show brood per given bark area.

An interesting point in this table is that 65% of the females were present in Trap Tree #1, with an average gallery length of 3.36 inches, 78% of the females were present in Tree M-3, with an average gallery length of 3.47 inches, and 88% of the females were present in Trap Tree #2 with an average gallery length of 2.36 inches. It would be expected that a greater percentage of sexes would occur at or near the beginning of egg-gallery construction, which is the case in Trap Tree #2. The fact that M-3 was standing may have made conditions more favorable than in Trap Tree #1, since the average length of galleries in Trap Tree #1 is less than in Tree M-3.

An analysis of brood per given length of egg gallery in the 3 trees already mentioned is shown in Table 6, which follows.

Table 6
Individual Attack Records

Tree	Distance from base in feet	Length of egg gallery in inches	No. of Eggs	No. of Larvae	Total Brood
Trap 1	10		0	0	0
			7	0	7
		1½	19	0	19
		1	48	0	48
		2	64	10	74
		2½	62	28	90
		2½	51	49	100
		3	45	34	79
		3½	39	40	79
		4½	16	116	132
		4	17	114	131
		5	29	102	131
		5½	60	139	199
Trap 2	6	1	24	0	24
		2	41	0	41
		2½	74	22	96
		4½	42	40	82
		5½	72	82	154
	16	2	31	0	31
		4½	25	85	110
	26	1½	29	0	29
		2	43	0	43
		3	82	0	82
M-3	15	1	0	60	60
		1.5	0	68	68
		2.5	0	102	102
		3.25	0	124	124
	66		0	0	0
		3	17	0	17
		3.50	9	13	22
		4.50	6	11	17
		5.50	22	16	38
		6	22	28	50
	73		0	0	0
		3	33	18	51
		4.50	17	43	60
		6	30	26	56

From the above table it is seen that the brood per length of egg gallery is quite variable. Bark thickness probably has an important influence on the number of eggs laid. In Trap Tree #1 the counts were taken from bark 10 feet above the base. Comparing the counts on Trap Tree #1 with counts 6 feet from the base on Trap Tree #2, and 15 feet from the base on Tree M-3, the number of brood per length of gallery is about the same. Bark thickness at these points on the three trees is also about equal. Counts made farther up on Trap Tree #2 and Tree M-3 show a marked decrease in brood per length of egg gallery.

Notes on Life History

Attacks. During June, July, August and the first week in September, new attacks are made on standing green trees, corresponding to the emergence period of new adults from overwintering generations. Since only a small number of adults emerge during the last week of May and the first half of June, new attacks are scarce at this time. During the 1930 season the first record of a new attack was taken from a tree felled June 24, at which time abrood of eggs and week-old larvae were found. New attacks were commonly found after this date until the first week in September.

When attacks are made the adult bores through the bark on an upward slant, choosing preferably a crevice in which to get started if the bark is thick. When the sapwood is reached a nuptial chamber is hollowed out, which grooves the inner bark next the sapwood and often grooves the sapwood. Photo 3 shows the entrance hole, nuptial chamber and egg gallery of two new attacks as they appear on the inner bark (see also Photo 4).

The number of attacks on a given unit of bark area are extremely variable, though four attacks per square foot is considered about average. Only one male and one female are present per attack after the egg gallery is ~~completed~~ started, but which of the sexes makes the initial attack is not known. The female is thought to be responsible.

Eggs. The construction of the egg gallery is done entirely by the female, while the male remains either in the entrance hole or in the nuptial chamber, where he evidently acts as a guard against enemies. Eggs are placed singly in niches along each side of the egg gallery, where they are packed in tightly with borings and frass material. The number of eggs laid per unit length of gallery is variable, from 35 to 45 per inch being the usual number. The average length of egg gallery when complete is from 4 to 6½ inches, which means that the number of eggs to be found in an egg gallery may vary from 100 to 300. With 4 attacks per square foot, a total of from 400 to 1200 eggs may be found. Further data on the number of eggs are found in Tables 5 and 6.

The egg-laying period extends over 4 to 6 weeks, and the resultant brood are of variable ages. Incubation lasts from 10 to 14 days, so that while eggs are still being laid, larvae are extending their channels, which may be from 0 to 1½ inches long. As soon as the female parent adult has completed egg laying she backs down the gallery and into the entrance hole, where she remains, head in, and dies, thus plugging the entrance hole with her dead body.

Larvae. As soon as the larva emerges from the egg it starts feeding in a channel which it constructs at right angles to the egg gallery. The channel grooves both the inner bark and the surface of the sapwood, and becomes more pronounced as it lengthens and the larva increases in size. By the time the larva is fully mature the channel is from 4 to 5 in. long. Larval development is rapid, though not to the extent of many of the bark beetles. Larvae which began their development by the middle of July were nearly mature by the first of September, and many had already bored into the bark to spend the winter in the prepupal stage. Since, as indicated on the life history chart (Fig. 2), the largest proportion of attacks are

MAINLY DURING THE latter part of July and the first part of August, the larvae which develop are in all stages of growth by the time cold temperatures force them to hibernate for the winter. Six to eight weeks may be considered the usual time required for the larval period at ordinary summer temperatures (see Tables 3 and 4).

Pupae. When the larva is fully mature it bores for a short distance into the bark, where a pupal cell is constructed. The position of the cell with reference to the outside is evidently dependent on the thickness of the bark and the temperature influences, for if the bark is quite thin the larva bores into the sapwood to pupate. If it is thick, the larva bores a considerable distance into the bark.

Pupation takes place at first during the middle or latter part of May and from then on as the larvae become mature. This resting period is from 10 to 15 days.

Adults. Adults appear about the first of June, and from that time on during the summer months, when they attack new green trees and establish new broods.

The adult S.ventralis is a shining black, cylindrical bark beetle, varying in size from 3.75 to 4.25 mm., and answers more nearly the original description of S.subcostar Lec. (Am.Phil. Soc.Proc.15:371-5,1876) than the original description of S.ventralis Lec. (Am.Nat.Soc.Proc.Tr.no. 2:169,1863), though the two may be synonymous. Swaine's description of Xylocleptes ventralis Lec. agrees quite well with specimens collected during this study, but not in all respects. Further studies are necessary in order to differentiate S.subcostar and S.ventralis, as well as to establish the identity of a third insect which cuts an L-shaped egg gallery in white and red fir, but which does not fit the description of either S. ventralis or S.subcostar.

Conclusions. On the basis of analyses made on 127 separate attacks in 1930 trees, certain conclusions in regard to life history are made. (1) Only one male and one female are present per attack. It is not definitely established which of the sexes enters the tree first, but at the time the nuptial chamber is made, both sexes are present. (2) The male remains either in the entrance hole or in the nuptial chamber, while the female extends the egg gallery and lays eggs. (3) Copulation was noted by J.C. Johnson to take place in the entrance hole; the female walks backward in the egg gallery until she joins the male in the entrance hole near its opening into the egg gallery. (4) The male abandons his post in the entrance hole before the female has completed laying eggs, but what becomes of him after that is at present conjectural. (5) After they have completed laying eggs, in most instances the females crawl to the entrance hole and die, head in, thus plugging the opening with their dead bodies. (6) Single egg galleries are completed within 5 to 7 weeks after attacks are established.

Swaine, J.M. Canadian Bark Beetles, pt.2, Bul.14, pp.53,54.

Parasites. The fact that the relationship of brood started to beetles emerging in a given generation is very small has already been indicated. The most important single factor observed to contribute to the reduction of brood is parasitism. One parasite of particular importance identified by DeLeon as Coeloides brunneri Vier. has been found to contribute to the reduction of large numbers of D.ventralis larvae. According to notes from DeLeon, this is also an important parasite of Dendroctonus pseudotsugae in Douglas fir. He states that it has also been reared from Scolytus tsugae in hemlock.

The life history of Coeloides Brunneri has not been worked out, though the notes obtained on it during the 1930 summer season indicate about the same sequence of development as found by DeLeon* for Coeloides sp., which is parasitic on Dendroctonus monticolae. Between May 23 and June 6 broods of D.ventralis larvae from the 1929 generation were in many instances noted to be heavily parasitized; the cocoons of parasites were found in place of f mature D.v. larvae at the end of the larval galleries. A collection of cocoons were put into rearing May 29, and on June 6 nearly all of them emerged. Large numbers of C. Brunneri emerged from the logs in the rearing cages between June 23 and July 16. Since the 1930 generation of D.v. larvae were not very far developed between these dates, it is reasonable to suppose that C.brunneri adults would parasitize D.v. larvae of the 1929 brood still in the bark. Further evidence of parasitism of 1929 broods of larvae by C.brunneri during June and July is supported by the cocoons which were found in September on several of the 1929 D.ventralis trees.

Heavy parasitism of 1930 broods by C.brunneri was noted August 25 on Tree M-4, when many females were observed to be ovipositing. The parasite brood developed in this generation of D.v. will probably emerge during July 1931.

Another parasite of less importance, and thought to be parasitic on D.ventralis, is a Pteromalid determined by DeLeon to belong to the genus Cosidosticha. Little is known of its life history, though it emerges about the same time as C.brunneri.

Predators. Two predators were noted in this study to be of considerable importance, though it is quite apparent that neither of them is as important as the parasite C.brunneri. The ostomid Temnochila virescens is the most common predator, and undoubtedly accounts for large numbers of D. ventralis larvae. Enoclerus lecontei Lec. is the common clerid predator, as indicated by considerable numbers of this species attracted to newly-attacked tree trees. It is interesting to note in this connection that E. lecontei has not heretofore been reported from white fir. The larvae of this species were found to be quite common under the bark. At least two other clerid larvae were noted with 1929 broods of D.ventralis, one of which is thought to be that of E.sphegeus. Attempts to rear the larvae during the summer proved unsuccessful.

*DeLeon, Donald. The parasites, predators and associated insects of the mountain pine beetle (Dendroctonus monticolae Hopk.) in lodgepole pine. Forest Insect Field Station, Coeur d'Alene, Id., May 15, 1930; Chart I.

Study of Fungus Infection

It has been repeatedly observed in connection with successful S.ventralis attacks on living green trees that a small dead area results for some distance vertically from each side of the attacks. The resultant deadening appears as a brownish discoloration on both the inner bark and the surface of the sapwood (see Photos 3 and 4). As pointed out by Miller, this enables the beetles to get established and rear broods in a live tree by killing patches without causing the death of the tree. If a tree is not killed outright, the deadened areas are soon healed over by a new growth of wood and bark, which forms a blister-like scar on the surface of the bark and leaves the record of the attack buried in the wood (see Photos 7 and 8). Miller and Craighead have suggested the cause of deadening to be the result of a fungus or bacterial organism associated with S.ventralis adults. As a result, an attempt to isolate the "infective organism" was begun soon after the first 1930 attacks were made on green trees. Trap Tree #1 served as a source of material from which the first cultures were made.

Preparation of Culture Medium

An extract of white fir bark (green) was made by boiling several pieces of bark in 250 cc. of water for one-half hour. The extract was drained off and to it was added approximately 3 grams of agar-agar shreds. The mixture was then boiled until the agar had thoroughly dissolved, and the resultant medium was poured into sterile petri dishes for plate cultures and then into sterile test tubes for slant cultures.

Cultures

The new attacks on Trap Tree #1 showed excellent developments of stain and gave promise of good material from which to prepare cultures. On July 10 four petri dishes containing agar media were plated with infected inner bark, using technic as follows: With a sharp scalpel, sterilized by flaming, the surface of the stained area was cut away to expose the infected area beneath. Then with sterilized forceps splinters were placed in each of the four petri dishes containing agar medium. The dishes were then inverted and set aside to await developments.

On July 14 the cultures were examined, and it was found that a healthy fungus growth had developed from each of the splinters planted in the four petri dishes. Colonies one-half inch in diameter had already developed around some of the splinters, producing a yellowish-brown discoloration in the agar similar to the stain effect on the surface of the sapwood and inner bark where new S.ventralis attacks are made. On the surface of each colony a whitish mycelial flocculence appeared. Transfers of the fungus colonies were then made to the agar slants in test tubes by the use of flamed dissecting needles. Careful technic, by flaming the mouth of each tube before and after each transfer, made it possible to obtain pure cultures which developed three days after the transfers were made.

Inoculation Experiments on Standing Green Trees

Three lines of experimentation were undertaken, as follows: (1) to determine whether trees could be artificially inoculated; (2) to find out what effect inoculation had on green trees, with an idea of whether they could be killed; and (3) to study the healing-over on trees artificially inoculated compared with the scars produced by infection associated with beetle attacks. The two last groups of experiments followed as a result of the first series after successful inoculations of fungus cultures had been made.

Artificial inoculation with fungus cultures. Four trees, In-1,2,3 and 9, were used in this study, representing fast, moderate and slow-growing trees of codominant, intermediate and suppressed crown classes in a second-growth stand near the Stanislaus Branch of the California Forest Experiment Station. Since this phase of the work was entirely new, a method of inoculation had to be worked out. A drill 3/32-inch in diameter was chosen as nearest the size of the egg gallery made by S.ventralis adults. Holes were drilled through the bark on a tangent to the sapwood, so that a considerable groove was made on the surface of the sapwood. By means of a flamed needle the inoculations were made by introducing a bit of agar that contained the fungus culture. Each inoculation was done as quickly as possible to eliminate contamination from the air.

The results of the inoculations were immediate. The first three trees inoculated were found to be infected within six days, giving an identical stain spread from the point of inoculation to the spread occurring from S.ventralis attacks on living trees. Not all the points of inoculation were examined at the same time to see whether infection occurred at the same rate, but later examinations showed that all were positively successful. A spread vertically of 1½ inches on each side of the point of infection was found to be about the average development (see Photo 9).

Artificial inoculation with crushed beetles. In this experiment a number of S.ventralis adults were taken out of the rearing cage and ground into a paste after the addition of sterile water. The inoculum thus produced was introduced into 12 drill holes on Tree In-4. After a period of one month all points of inoculation had begun to heal over, with no further injurious effect than that caused by mechanical injury.

Artificial inoculation to determine lethal effect. Tree In-5 was used in this experiment, in which the points inoculated were in spiral arrangement around the trunk, so that girdling would result if the fungus developed to the same extent as in Trees In-1, 2 and 3. This tree will be left intact until next season to determine what effect the fungus has had on the tree.

Artificial inoculation to determine heal-over effect. Trees In-6,7 and 8 were inoculated with the fungus cultures with the object of comparing the scars produced with the scars on green trees caused by infection from beetle attacks. These trees will not be disturbed until next season, when it is hoped that a record of the effect of healing can be obtained.

The descriptions of trees used in these studies and the results of inoculation are summarized in Table 7, which follows:

Table 7

Summary of Inoculation Studies

Tree #	Crown Class	DBH	Ht.	Bark Thick-ness	Growth Rate	Date Inoc.	No. Inoc-ulum	Date of Exam.	% of Points Infected	Max. Fungus Spread
In-1	C	10	50	Med.	Mod.	7/17	5	7/25	100	5"
In-2	S	4	30	Thin	Slow	"	7	7/21	100	2½"
In-3	C	8	40	Thick	Fast	"	12	7/23	100	2½"
In-4	I	4	25	Med.	Mod.	"	12	Healed over		0
In-5	S	2	10	Thin	Slow	7/29	20	Fungus	To study lethal eff.	
In-6	C	3	18	"	Fast	7/29	10	"	Healing-over study	
In-7	C	10	40	Med.	Med.	8/ 8	10	"	do	
In-8	I	6	30	"	Slow	8/ 8	10	"	do	
In-9	C	6	40	"	"	8/ 8	10	10/20	100	2"

As seen in Table 7, the growth rate, crown classes and bark thickness varied considerably in the trees inoculated; but this apparently had very little to do with infection or spread of the fungus stain. The rate of development of the fungus in the fast-growing tree In-3, with fairly thick bark, seemed somewhat slower than in the others, but this may have been due to lower temperatures under the bark, which retarded the development.

Check Trees

These trees were drilled with the 3/32" drill on June 30, but were not inoculated. The only possibilities of infection came from the unsterilized drill and from the air. All trees used here were approximately of the same growth rate, crown class and diameter as the inoculated trees, although exact measurements of diameter and height were not obtained. Nine trees were drilled, and in no case did infection of any kind result by the end of the summer months. The trees had healed over the wounds in every instance where examinations were made (see Photo 10).

Three of the weak points in the inoculation experiments are pointed out as follows: (1) The drill was not sterilized while boring the holes to be inoculated; (2) The holes were not closed after inoculation, and thus contamination from the air might result in an infection; (3) No attempt was made to determine what effect the agar had on the trees.

The first two weaknesses are prevalent in all the trees inoculated, and in no case did an infection result. What effect the agar medium, aside from the culture growing on it, had on the inoculated trees is not known, though it is certain that the infection did not result on account of the agar.

Re-culture from an Inoculated Tree

The objective in this experiment was to determine whether the infection resulting from inoculation would produce the same type of fungus colonies on agar as were used to inoculate the green trees. The bark covering the infected area on one of the attacks on Tree In-3 was removed and taken into the field laboratory. Using the same technic as in preparing the original fungus cultures, the surface of the inner bark was cut away.

splinters of infected bark were taken at some distance from the point where the inoculation was made and planted on agar plates. Two plates were prepared on July 23, and by August 2 a pure, healthy growth of fungus colonies resulted which were identical with the first ones.

Inoculation of a Green Log

On July 23 a green log 4 inches in diameter by 3 feet long was inoculated to determine what infection might take place. Twenty holes were drilled and inoculated in the manner already described. By August 4 a good growth of stain showed up in one of the galleries. A stain spread was found from all points of inoculation when examined later in the season.

Culture from 1929 *S.ventralis* attack

A culture was made by plating splinters of surface-stained sapwood from a 1929 *S.v.* attack on a log in the rearing cage. One agar plate containing 8 strips was plated August 6. On August 12 good growths of fungus were recognized as identical to the other colonies studied. This indicates that spores are abundant under the bark of dead trees containing broods of *S.ventralis* that are about to emerge. It would therefore be expected that the emerging *S.ventralis* adults would carry the spores to new green trees which they attack. However, judging from the inoculation of Tree Ip-4 with crushed adults, it is evident that not all of the beetles carry spores, for on this particular tree not one of the points of inoculation showed fungus infection.

Culture of *S.ventralis* adults

Three *S.v.* adults were taken from the rearing cage on August 6 and plated in toto on the surface of a petri dish containing the agar culture medium. On August 15 many colonies of fungi had developed, but not a single colony resembled the stain fungus. This experiment indicates that either not all the beetles carry the stain fungus or that the spores were lost after the beetles had emerged from the bark and spent some time on the walls of the rearing cage.

Controlled Forced Attacks of *S.ventralis* on Caged Green Trees

The apparent ability of *S.v.* to attack and successfully establish broods in trees at random, without regard to vigor or growth rate, during 1929 and in previous seasons, led to the belief that by forcing attacks on caged green trees they might easily be overcome by the beetles. This method of experimentation has been used in the study of the western pine beetle[1] and proved to be very satisfactory regardless of tree growth, provided sufficient beetles were introduced to overcome the resistance of the tree. The necessity of obtaining conclusive data on the development of *S.v.* broods in standing trees, and the resulting development of an associated fungus stain, also made it more expedient that the caging experiments be tried. These experiments were started at the beginning of the emergence period in 1930. The beetles were obtained from the rearing cages described earlier in this report.

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[1] Person, H.L. Report on Western Pine Beetle Studies of 1927. Genecal Unit, Northfork, Calif.; May 30, 1928.

Description of Cages. Cages of the screen cylinder type were constructed about trees from 8 to 12 inches in diameter, using one width of 18-mesh screen, which is 40 inches wide (see Photo 5). The edges of the screen were fastened along one side of the tree by tacking them between two ¼x¼" strips. The top and bottom ends were drawn in tightly and wired against strips of cotton batting to prevent the escape of beetles. Beetles were admitted to each cage by a small hole cut in the screen at the bottom. The hole was kept closed by a plug of cotton. Screen 40 inches wide left considerable space within the cage on trees of the diameters used in these experiments. Three of the cages were constructed on approximately 12 feet of trunk, using galvanized iron screen, and two of them on approximately 17 feet of trunk, using copper screen.

Cages on Standing Green Trees. Cage #1 was built about 12 feet of the trunk on a tree 12 inches DBH and 45 feet high, and of fairly rapid growth rate (see Fig. 4 for growth rate). Between June 24 and July 6, 1,094 S.Y. adults were admitted from the rearing cages. A good attack had started on July 2 and heavy balsam flows were noted after this date. The cage was taken down July 26 and some examinations were made to determine the success of attacks, but none was found to be successful. The tree was felled and analyzed on August 8. It was found that out of the 1,094 beetles introduced, only 390 attacks reached the sapwood, where egg gallery construction is ordinarily started. Very few egg galleries were begun, the longest of which was 1.75 inches, and none of them was successful (see Photo 6). Heavy flows of balsam took place as each attack was made, and at the time of analysis no living beetles were seen.

Cage #2 was constructed around 12 feet of a tree 10" DBH and 60 feet high and of medium growth rate. (See Fig. 4 for growth rate). Between July 10 and August 8, 2,400 S.Y. adults were admitted from the rearing cages. On August 4 a number of borings and flows of balsam indicated a good attack. On August 20 the cage was taken down and the tree felled for an analysis of the caged portion.

It was observed on Cage #1 during analysis that a considerable number of attacks were made on the inner bark which never reached the cambium and outer sapwood. Consequently, when Tree #2 was analyzed separate counts were made on the number of attacks reaching the inner bark. These analyses showed that out of the 2,400 beetles introduced, 2,160 attacks reached the inner bark and only 81% reached the cambium and outer sapwood. Egg gallery construction was little more successful than in Cage #1. Two galleries contained eggs: one of them, which was 5 inches in length, contained 2 eggs, and another, 2.5 inches long, contained 4 eggs. Both galleries were badly "pitched" at the time of examination and were abandoned, as were all the other attacks on the log.

Cage #3 was constructed about a suppressed tree of very much slower growth rate than either #1 or #2, as shown by the comparative growth curve in Fig. 4. This was also a 12-foot cage, constructed about a tree 7 inches DBH and 33 feet high. 570 S.Y. adults were introduced from the rearing cages between August 5 and August 12. This tree was felled and analyzed on September 4, and it was found that 1,140 attacks were made on the inner bark, 348 of which reached the outer sapwood. Of the 348 attacks, many contained egg galleries over ½ inch long, several were over 1" long, four were 2" long and one was 3" long. In spite of the gallery length, however, not a single egg was laid, and at the time of examination the tree was abandoned and all galleries and attacks were badly [illegible]

Cage 4 was constructed around a tree 12 inches DBH and 50 feet high, and which was quite fast-growing, as shown by the growth curve, Fig. 4. Between August 13 and September 5, 710 S.v. adults were admitted to the cage. This cage was not disturbed until November 4, when it was taken down. The tree was at this time felled and analyzed to see what development had taken place, and it was found that 1,382 attacks reached the inner bark. Of this number 673 reached the outer sapwood. The longest egg gallery was found to be ½ inch in length, but most of the attacks merely touched the surface of the sapwood, with no further development.

Cage 5 was of the same type as #4, but built around a slower-growing tree (see Fig. 4 for growth rate), 8 inches DBH and 50 feet high. 715 beetles were introduced between August 13 and September 3. This tree was left standing for the winter, but will be felled and analyzed next season.

Results. A summary of the results of the caged-tree experiments is shown in Table 8, which follows.

Table 8

Summary of Caged-Tree Experiments

Cage #	Caged DBH	Length of Trunk	Dates: Beetles Introduced	Dates: Beetles Admitted	Total S.v.	No. attacks on inner Bark	No. attacks on Sapwood	Long. gal.	% attack with Stain	Date of Analysis
	"	ft.								
1	13	18	6/24	7/ 8	1,094		390	1.25	49	8/ 7
2	10	18	7/19	8/ 5	2,400	2,160	316	2.5	80	8/20
3	7	12	8/ 5	8/12	570	1,140	348	3.0	92	9/ 4
4	12	17.5	8/13	9/ 5	710	1,382	673	.75	0	11/ 4
5	8	17	8/13	9/ 2	715					

It is noticed in the above table and in the preceding accounts of the caged trees, that the number of attacks reaching the outer sapwood is very much less than the number reaching the inner bark. It is also seen that the number of attacks made outnumber the beetles introduced, especially in Cages #3 and #4. Both these facts indicate that conditions were probably not favorable for the beetles to become established, and that as a result they attacked here and there along the trunk with little success. This fact is especially surprising on Caged Tree #3, which was a very slow-growing, suppressed tree. The attacks made on this tree showed more promise than those on any of the others, but in spite of it none of them was finally successful.

The suggestion was made by Mr. Miller that perhaps the feeding habits of the beetle required greater investigation; that beetles taken from the rearing cages were not mature enough to bore directly into the bark of a green tree and establish a brood. This idea is borne out by a rearing experiment on two green logs, primarily intended as a parasite study.

Cages on Trap Logs

A square cheesecloth cage, 30x30x30 inches high, was constructed with a partition in the middle to divide it into two equal compartments. In each compartment was placed a green log, 8 in. in diameter by 8 ft. long. One hundred D.ventralis adults were taken from the rearing cages and placed with each log between July 14 and 18. Between July 19 and 23, 100 parasites, Coeloides brunneri, were put in with one of the logs. By August 10 a good brood was started, with larvae already showing up. None of the parasites could be found on this date, indicating that they had all died, since they could not escape. It is doubtful that any of the D.v. brood was parasitized so early in development, though this will not be known until the broods are reared.

The interesting point in this experiment is the fact that successful D.ventralis broods were reared from parent adults taken directly from the rearing cage and put with the green logs, indicating that a flight or feeding period is not necessary for successful brood development. The fact that the beetles were not able to become successfully established in the caged trees indicates more a resistance on the part of the tree which the beetles were not able to overcome. This is especially surprising, since so many trees were killed by beetles in 1929, many of which were faster-growing at the time of death than those used in the caging experiments. A chemical difference between different trees or different portions of the same tree may also be present, which would tend to influence the success of an attack.

Fungus Stain Development in Relation to D.v. Attacks

1. Caged Trees. Referring to Table 5, the percentage of attacks which show a definite development of the stain fungus is listed for each caged tree. In Cage #1, 49% of the attacks showed a definite stain development, and in Cages #2 and #3, 80 and 92% respectively of the attacks were definitely stained. In Cage #4 none of the attacks showed any stain development. Referring to the growth curves (Fig. 4) of the four caged trees used in this experiment, it is noticed that Caged Trees #1 and #4 show very rapid growth compared with #2, and especially with Suppressed Tree #3. From the table and the growth curves, a correlation between growth rate and stain development apparently exists, though the evidence is insufficient to support any definite conclusions on this basis. It is definitely shown, however, in the caged tree experiments, that the stain does not develop with every attack which reaches the cambium. Whether the stain develops at all, or the extent to which it develops, may be the key to the success of an attack.

2. Trap Trees. The development of stain in all the trap trees and in the standing green trees with new D.ventralis attacks was observed to be quite consistent with successful attacks. Where the analyses were made on separate attacks on Trap Trees #1 and 2 and #4-5, to determine brood abundance, account was also taken of the stain spread with each attack. The following summary table gives a record of the average stain spread and its prevalence, figured with 186 separate attacks on the three trees mentioned:

Table 9

Fungus Stain Development

Tree #	No. of Attacks	Av. Length Egg Gallery	Spread of Fungus from Egg Gallery	% of Att. with Stain	Av. Length of Gallery without Stain
Trap 1	71	3.47"	2.90"	100	
" 2	67	2.56"	2.18"	89	.84"
M-3	50	3.47"	2.32"	100	

The relationship between attacks and stain spread, as shown, is quite consistent. Whether it has any bearing on the success of a brood is not known, though as shown by Table 5, the brood development per attack in these trees is quite high. In Trap Tree 2, 60 out of 67 attacks developed stain. The 7 attacks without stain development had an average gallery length of .84 inch, which may mean that the fungus either had not begun to develop or that it was never introduced by the beetles. No brood had developed in this gallery.

Forced S.mutrulis attacks in Drill Holes

Three trees were used in this study, to determine whether fungus spores were carried by the beetles which emerged from logs in the rearing cage, and also to study the habits of beetles introduced in this way. The holes were drilled at an angle, as in the trees where fungus inoculations were made, with the 5/32" drill described earlier in this report. One S.v. adult was placed in the entrance of each hole, where it willingly went into the hole without backing out again. Observations made on these trees later indicated that the beetles had found conditions favorable, judging from borings which filled several of the holes.

Following are descriptions of the trees and the results obtained in this study:

Table 10

Tree #	Date S.v. Introduced 1930	D.B.H. (inches)	Height feet	No. Holes	Date Holes Drilled	Examined 1930	Max. Length of Galleries, inches	% of Holes with Fungus Stain
DHH-1	8/ 4	8	45	9	8/28			100
" 2	8/14	12	40	12	"			100
" 3	"	18	40	12	"			100

On August 28, when all the holes were examined to note what progress the beetles had made, it was found that none was present. In most instances the beetles had bored for ¼ to ½ inch, grooving the surface of the sapwood, but no definite egg galleries were constructed. It was noted in each case, however, that a good fungus growth was established, staining the inner bark and sapwood.

The results of this experiment indicate that S.v. adults taken from the rearing cage carry the fungus spores, in spite of the results obtained by culturing the adults and by inoculating with crushed S.v. adults.

Effect of Stain on Sapwood and Inner Bark

The yellowish browning of the entire living portion of the inner bark, cambium and surface of the sapwood as a result of the fungus has been indicated. As the stain develops, the portions over which it spreads rapidly become drier than the greener portions. As an egg gallery is extended the stain development is least at its newest portion, becoming more widespread where the attack was initiated. The bark and wood around the attack are soon considerably drier than the greener portions, and thus may have a definite bearing on the success of a brood.

Identity of Fungus

The difficulty of establishing this fungus in a definite niche in relation to systematic classification was hinted early in the summer by H.H. Wagener, Pathologist, U.S. Bureau of Plant Industry. Specimens of the stain on the wood following S.ventralis attack and a tube culture of the fungus were sent to Dr. C.T. Rumbold at Madison, Wis., during August for possible identification. A reply from her later stated that she thought the fungus was a Verticillium, but that a more positive identification was possible from Dr. C.D. Sherbakoff of the University of Tennessee Agricultural Experiment Station, located at Knoxville. She accordingly sent cultures to him, and he identified it "to resemble very much a Verticillium". According to Dr. Sherbakoff "it has certain peculiarities, such as for instance often very dense bunching of the sterigmas, gray mycelium and globe-shaped conidia, the characters by which it perhaps could be readily distinguished from other related forms, or possibly placed in another genus".

Cultures of the fungus were also taken to Dr. Lee Somr of the Department of Botany, University of California. His determination takes it to the genus Trichoderma Pers., on the basis of hyaline spores being borne in bunches at the ends of branching hyphae, though he states that he could not be sure of such an identification without further investigation of cultures grown on various media.

Tree Selection Studies

One of the newer aspects of this study became obvious following an epidemic of S.ventralis Lec. in 1929, when large groups of white fir were found to be killed (Photos 11 and 18). Losses were not confined to the older mature and crowded stands, but were also found to be quite heavy in the faster-growing second-growth timber. The latter losses appeared even greater than in the older stands.

At the outset it seemed that trees of no definite condition of growth rate or vigor were taken by the beetles; that there was no apparent preference for the weak and slower-growing trees, as has been shown* to be the case with the western pine beetle in western yellow pine. Definite conclusions on this point, however, could not be made except by studies on tree selection, and accordingly four plots were chosen for concentrated study in areas widely separated from one another, where group killings occurred.

*Person, H.L. Tree Selection by the Western Pine Beetle; Jour.For., May 1928.

On each plot individual tree records of all insect-killed trees and an equal number of green trees of similar or equal diameter-height class were taken. Cores were obtained from both dug and green trees by means of an increment borer, and the annual rings for each group were carefully measured and compared over a ten-year period, from 1930 to 1939 inclusive.

Location and Description of Selection Plots

Strawberry Plot. 1. Location: One-quarter mile SE of Strawberry Inn, near section line between Secs. 16 and 21 of T 4 N, R 16 E, surrounded by a cutover area logged not more than 8 years ago.

2. Purpose: To determine whether trees are selected according to growth rate or vigor in a young virgin stand between 90 and 100 years old, where a moderate amount of competition from crowding is going on.

3. Description: This plot of approximately ½ acre occupies a moderately steep northwest slope. Site I, in a stand consisting of 95% white fir and 5% sugar pine. About 150 trees compose the group.

During the 1929 season 69 white fir trees were killed outright by D.ventralis. In some cases 10 to 15 feet of the base was left green, but in others D.v. broods were found within 2 or 3 feet of the ground. Cores were taken from 27 of the insect-killed trees and from an equal number of green trees having similar diameters and heights, for the purpose of comparing the ring width covering the last 10 years preceding the death of the insect-killed trees. The ring measurements were taken in millimeters by means of a ring width gauge.

4. Results: Fig. 6 shows the curves of growth during this period for the two groups. It is readily seen from the graph that no selection by growth is evident; and it is therefore indicated that any of the trees in this stand are susceptible to beetle attack if growth rate is the only limiting factor of selection.

Water Tank Plot. 1. Location: About 5% corner of Sec. 19, T 4 N, R 18 E, about 10 chains from N end of South Fork (see map, Fig. 10); about ½ mile SW of the Stanislaus branch of the California Forest Experiment Station; parallel to the South Fork of the Stanislaus River; about 75 yards SW of a water tank of the Pickering Lumber Company Railroad, which parallels the river.

2. Purpose: To determine whether selection by growth rate is evident in a large group of trees killed by D.v. during 1929, in a pure virgin heavily-stocked white fir stand about 100 years old, where there is keen competition from crowding.

3. Description: Area of about ½ acre; steep northwest slope; Site I; pure virgin white fir where insects concentrated during 1929 in white fir-sugar pine type.

Twenty-five cores were taken from D.v. trees as follows: 23 from trees killed during 1929, 1 from a 1929 D.v. top-killed tree, and 1 from a 1930 D.v. tree. An equal number of cores were taken from green trees with similar diameters and heights. The average ring widths of D.v. and green trees were compared over the period from 1880 to 1929.

4. Results: Fig. 6 shows the curve of growth comparing the insect-killed and green trees. In this graph a consistent slower growth rate is shown for the D.v. trees, but the difference is insufficient to warrant much significance so far as selection is concerned.

Cold Springs Plot. 1. Location: Near NE cor. of NW¼ of Sec. 6, T 5 N., R 18 E; about 12 chains east of the old Cold Springs mill (see general map Fig. 9).

2. Purpose: To determine whether selection is evident in a pure vigorous second-growth white fir stand about 80 years old, where a group killing occurred during 1929.

3. Description: Area of about ½ acre; isolated stand of trees occupying a gentle west to northwest slope, Site II; surrounded by dense growth of snowbrush, Ceanothus cordulatus; surrounding area heavily logged about 1910; in white fir sugar pine-yellow pine type.

Seven trees of this group were selected by D.v. during 1929. Cores were taken from these trees and an equal number of cores from similar green trees were taken for comparison of ring measurements from 1880 to 1929.

4. Results. The comparative growth curves in Fig. 7 show quite a pronounced selection for the slower-growing trees. The average growth increment of insect-killed trees is 1.20 mm. less than that of green trees at the time of death, and from .80 to 2.00 mm. less for several years preceding attack by insects.

Leland Meadow Plot. 1. Location: One-half mile north of Leland Meadow, in NE¼ of Sec. 3, T 4 N., R 18 E (see general map, Fig. 9).

2. Purpose: To determine whether the group of trees killed in a vigorous 70-year-old second-growth stand were selected according to growth rate, and also to compare the results of the study with the Cold Springs Selection Plot.

3. Description: Area of about ½ acre, Site I, gentle south slope, pure second-growth white fir, logged about five years ago in white fir-sugar pine-yellow pine type.

Six trees were entirely killed by D.ventralis during 1928. Cores were taken from these trees, together with cores from 6 similar green trees, and a comparison of growth was made for the ten-year period, 1920 to 1929 inclusive.

4. Results: Comparing the growth curves of green and insect-killed trees shown in Fig. 8, the trees selected by D.F. were much slower-growing than the green trees. As on the Cold Springs Plot, the difference between the green trees and those selected by D.F. at Leland Meadow is sufficient to recognize a definite selection by growth rate.

Discussion of Results

It is evident in the case of the first two plots, Strawberry and Water Tank, that selection by beetles was a matter of chance; that any tree in the stand might as well have been chosen. This is especially true of the Strawberry Plot, since the growth of insect-killed trees is even slightly higher than that of the green trees for several years before death. The Water Tank Plot shows a consistent slower growth rate for the insect-killed trees compared with green, but the difference is not great enough to be of much significance, and it is felt that in this case the trees that happened to be slower growing than the green check trees. The difference in growth rate between insect-killed and green trees on this plot varies between .15 and .85 mm., which does not indicate a very great degree of selection.

The trees killed by insects in the second-growth plots at Cold Springs and Leland Meadow show definite selection by growth rate when compared with green check trees. Consistent slower growth rate is shown for the insect-killed trees over the ten-year period considered, with a greater difference occurring toward the end of the period. On the Cold Springs Plot the difference of growth increment on green and D.F. trees ranges between .75 and 1.50 mm. and on the Leland Meadow Plot it ranges between .90 and 1.95 mm. A difference in growth increment as great as 1.50 mm. at the time a tree is attacked does indicate selection. It is admitted at this writing that the number of trees compared on both the Leland Meadow and Cold Springs Plots was considerably less than that on the other plots, but the results are quite significant, since so great a difference in growth rate is shown.

Comparing all four plots, it is noted that the growth rate of green trees on the Strawberry and Water Tank Plots is considerably less than that of the insect-killed trees on the Cold Springs and Leland Meadow plots. For instance, the variation in growth of green trees on the first two plots ranges between .50 and 1.04 mm., whereas the growth variation of insect-killed trees on the last two plots ranges between .66 and 1.95 mm. This would indicate that any of the green trees on either the Strawberry or the Water Tank Plot are susceptible to beetle attack if growth increment is the only limiting factor to beetle attack. If this is true, such stands should be heavily thinned in logging practice.

Photo #1 (7310a) Old and recent top-killing in a mature white fir stand, due to the work of Scolytus ventralis Lec. The tree in the left center was top-killed many years ago, the old top having since decayed and fallen. Secondary leaders which developed at the base of the old kill were recently re-attacked and killed. The tree, right center, was top-killed several years ago, but the top has not yet decayed to the point of breaking off. Photo by J.M. Miller, 6/23/23.

Photo #5 (7347a). Triangular type cage used to enter S. ventralis Lec. adults from infested logs. The beetles, attracted to the high and by greater light intensity there, are easily collected.--Photo by C.M. Struble.

Photo #6 (7347). Bark removed from white fir log to show areas unsuccessfully attacked by S. ventralis Lec., where the beetles were forced on green trees by caging the trunks. The dark areas indicate points where beetles attacked but were forced out on account of unfavorable conditions.--Photo by J.M. Miller.

Photo #3 (7351)

Photo #4 (7369)

Spread of fungus stain in advance of larval feeding

Photo #3. New attacks of *S. bunkeralis* on inner bark surface (removed from log) showing spread of stain as egg galleries are constructed. The oldest part of each gallery is clearly indicated by more advanced development of stain. Note also entrance hole, nuptial chamber and egg niches in connection with each gallery.

Photo #4. Later development of stain on sapwood after larvae have begun to feed. The greatest extent of stain is associated with the longest larval channels and the least where eggs are still being laid. This is a section of a log with bark removed, exposing surface of sapwood.

Photos by J.M. Miller.

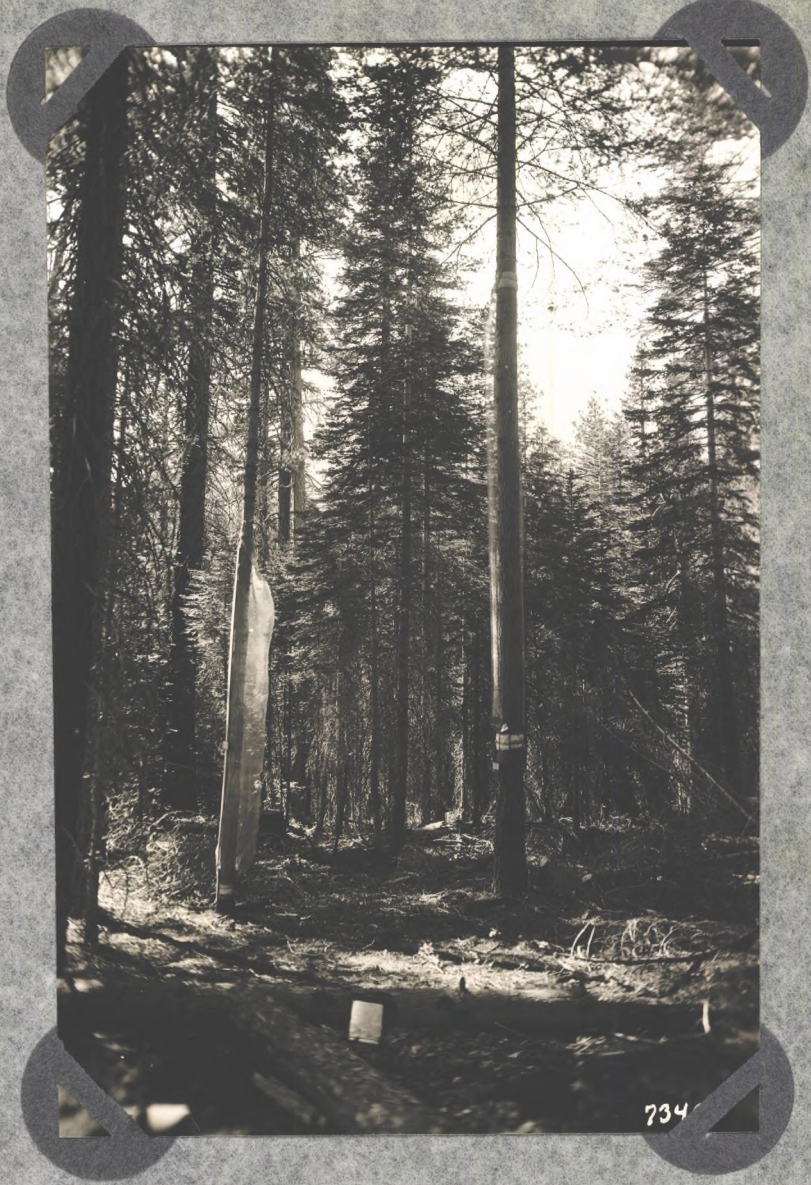


Photo #5 (7346). Cages used in white fir studies, where *S.ventralis* Lec. adults were forced to attack the trunk within the caged area. The cage to the right is 17.5 feet long, with the base 6 feet above the ground. Note the cotton plug at the base where beetles were admitted to the cage. The 12-foot cage on the left is constructed around the basal portion of the trunk.

Photo by J.M.Miller.

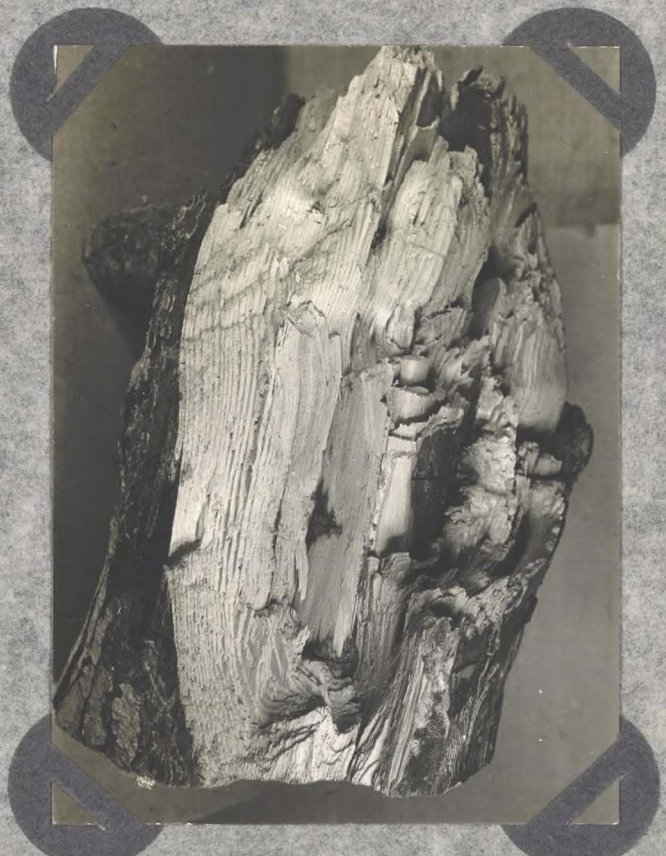


Photo #7 (7359a)

Photo #8 (7359b)

Photo #7. Section broken out below dead top of old top-killed white fir in such a way that S.v. attacks buried in the wood were exposed. Patches of cambium killed as result of egg gallery and fungus stain are shown in the darkened areas. The large darkened area at right center is an attack made about 1884, the year the top was killed. This tree was attacked in 1881, 1884, 1900, 1905, 1906 and 1927, but patches only were killed, the surrounding green wood healing over them. In 1929 a final attack killed the tree.

Photo #8. Cross section of block in accompanying photo, showing scars of old attacks buried in the wood, recording the year of attack by darkened annual rings. Note also the healed-over areas about each attack.

Photos by J.M. Miller.

Photo #9 (7349)

Photo #10 (7350a)

Artificial inoculation of green white-fir trees

Photo #9. Stain development in Tree Ib-3, in which a pure fungus culture was introduced by means of a dissecting needle after a hole had been bored with a 3/32" drill. The hole in the center indicates the point where the tree was inoculated. Spread of the stain in a vertical direction is shown on each side of the hole. No healing had taken place at the time this photo was taken. This tree was drilled and inoculated July 17, 1930. The bark was removed and the photo taken August 20, 1930.

Photo #10. Bark removed to show sterile healthy cambium of green tree drilled with 3/32" drill but not inoculated. The wood surrounding the wound has already started to heal over it. This tree was drilled June 20, 1930. The bark was removed and the photo taken August 20, 1930.

Photos by J.M. Miller.

Photo #11 (7548). Groups of pole-sized trees in second-growth white fir killed by S.ventralis Lec. attacks in 1929. Trees were in red foliage at time photo was taken (August 1930), and show white in photo through use of panchromatic film. Photo taken near Cold Springs, Stanislaus National Forest.

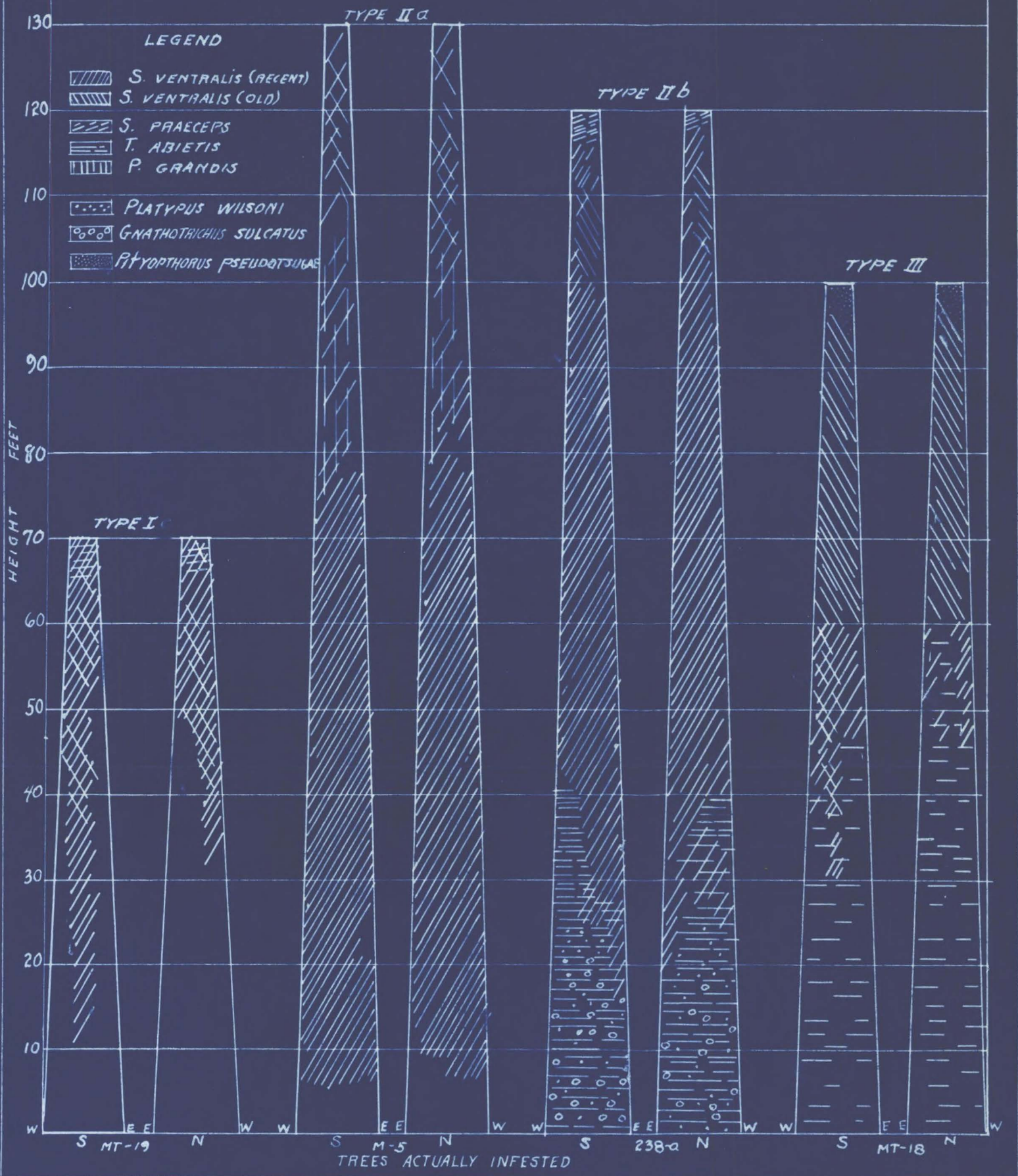
Photo by J.M. Miller.

Photo #12 (7244a). Large group of white fir trees killed in 1929 by S.ventralis Lec. along the shore line of Lake Tahoe, near Kennedy. Note the fading tops of two trees on the extreme right, the result of recent B.V. attacks. Groups of this type are a menace to the living trees surrounding them.

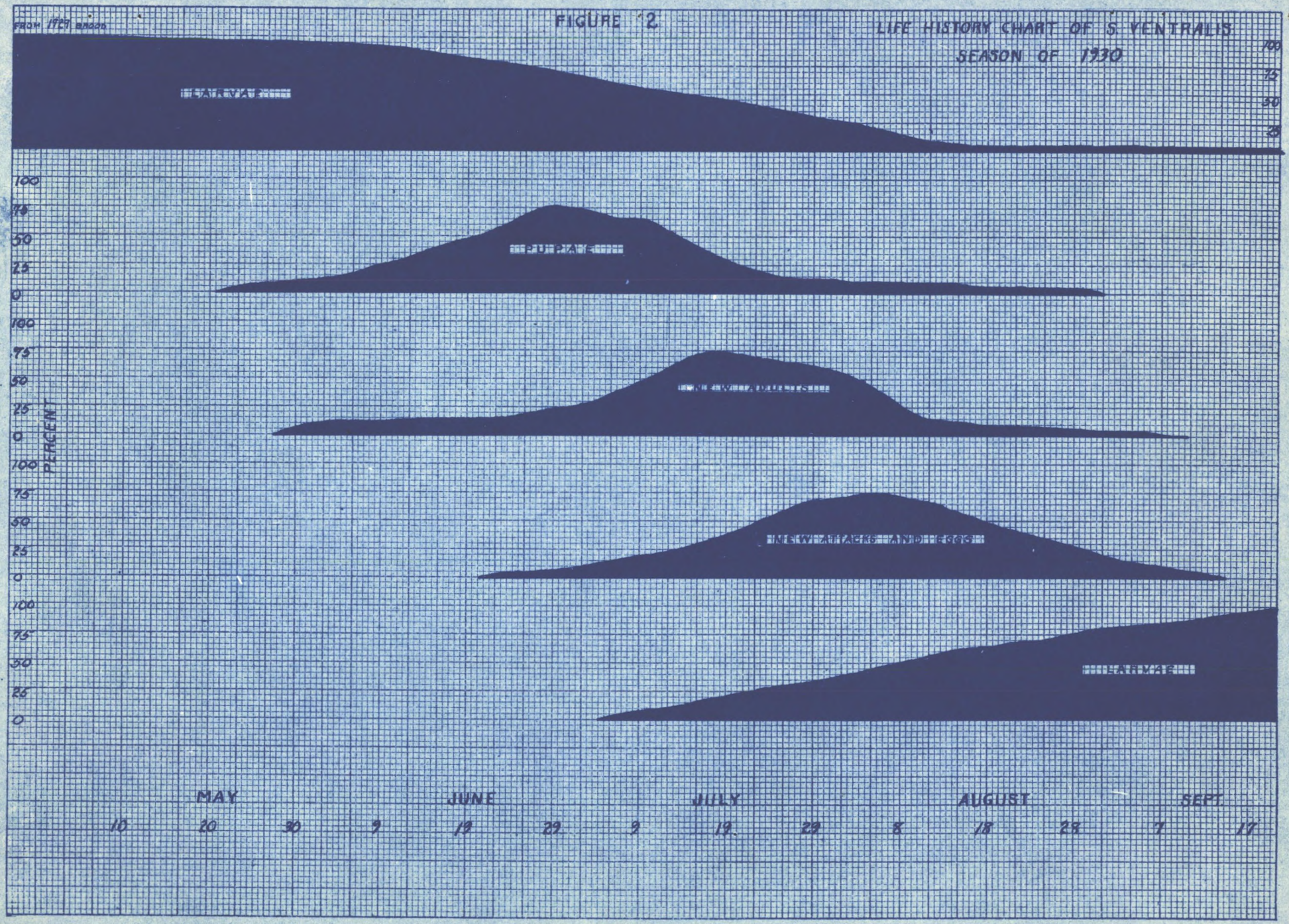
Photo by J.W. Miller.

FIGURE I

TYPES OF INSECT INFESTATION IN WHITE FIR



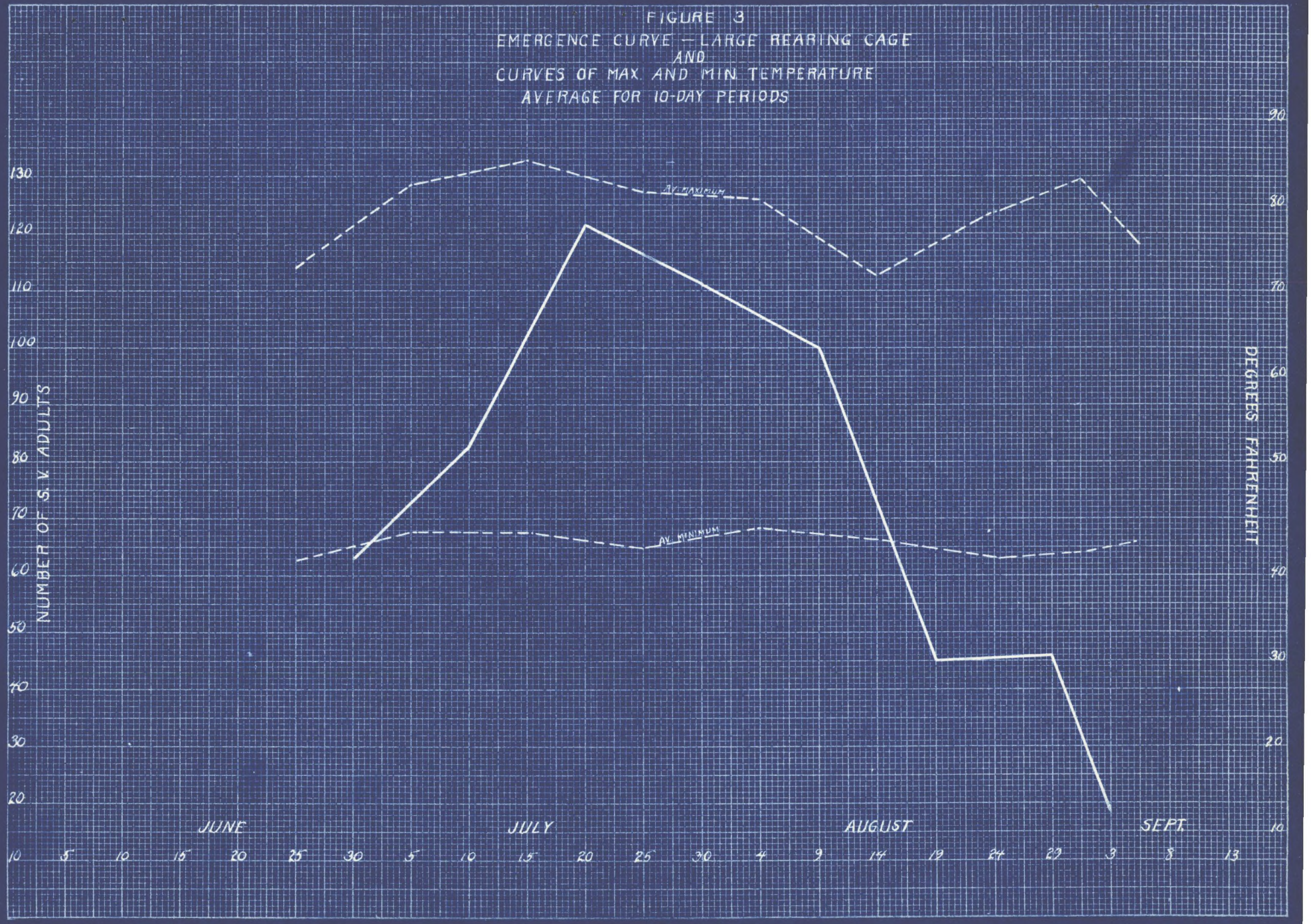
TREES ACTUALLY INFESTED



U. S. GOVERNMENT PRINTING OFFICE: 1928 8—6348

FIGURE 3

EMERGENCE CURVE — LARGE REARING CAGE
AND
CURVES OF MAX. AND MIN. TEMPERATURE
AVERAGE FOR 10-DAY PERIODS



U. S. GOVERNMENT PRINTING OFFICE: 1923 8—6348

FIGURE 4

CAGED TREE EXPERIMENTS
GROWTH CURVES OF 5 CAGED GREEN TREES OVER 11-YEAR PERIOD

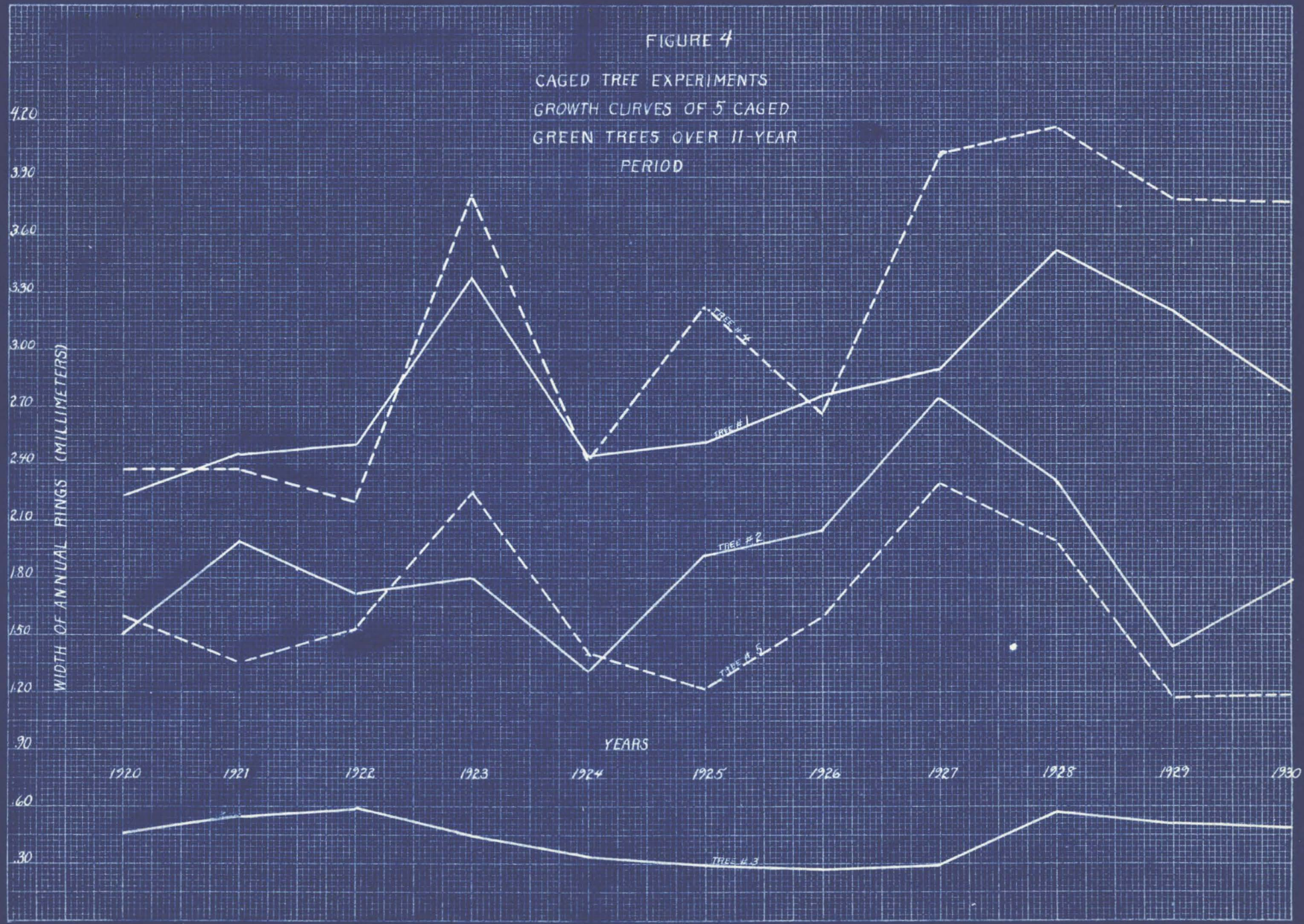


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FIGURE 5

STRAWBERRY TREE SELECTION STUDY
AVERAGE GROWTH RATE OF 27 GREEN AND 27 INSECT KILLED TREES OF EQUAL DIAMETER HEIGHT CLASS

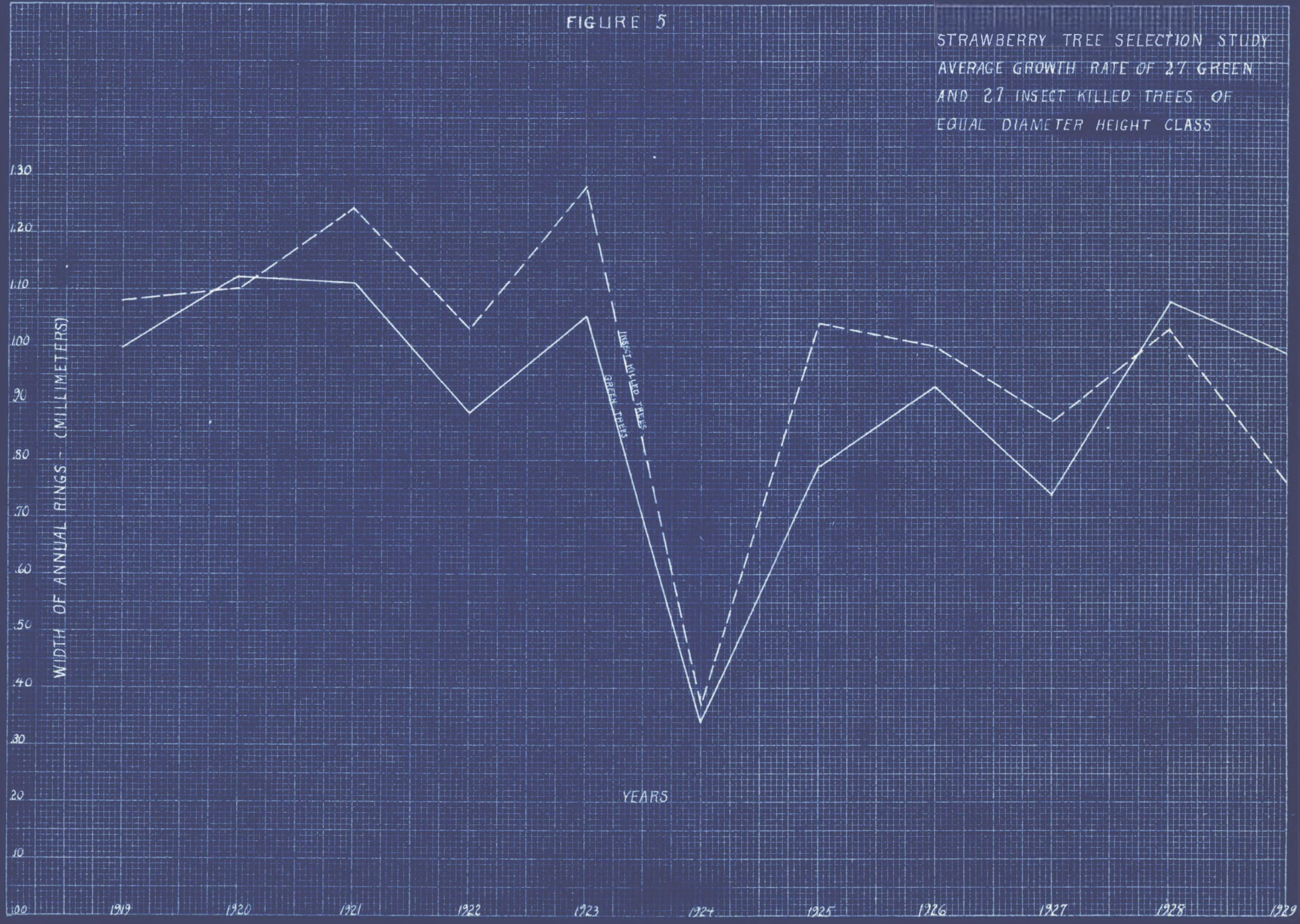
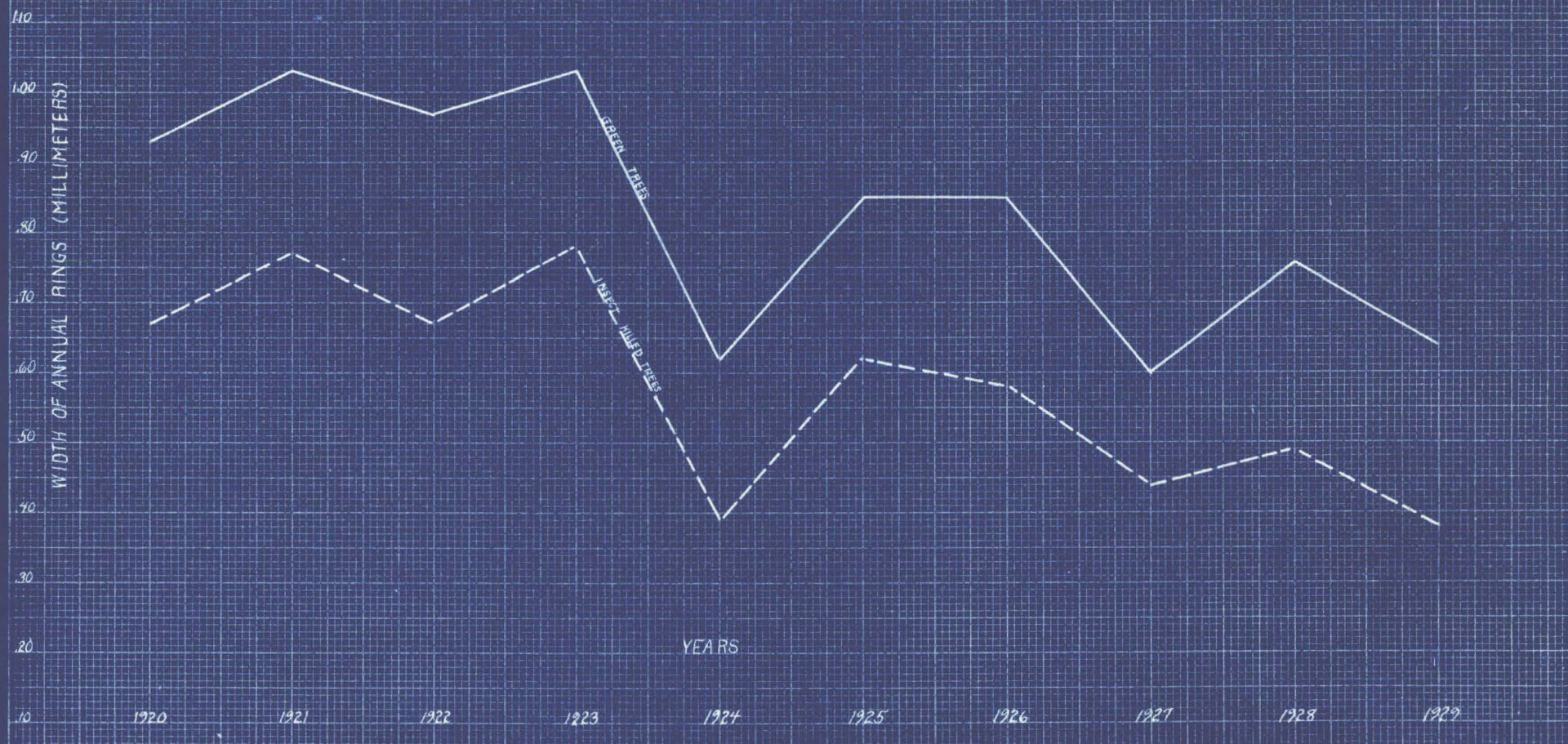


FIGURE 6

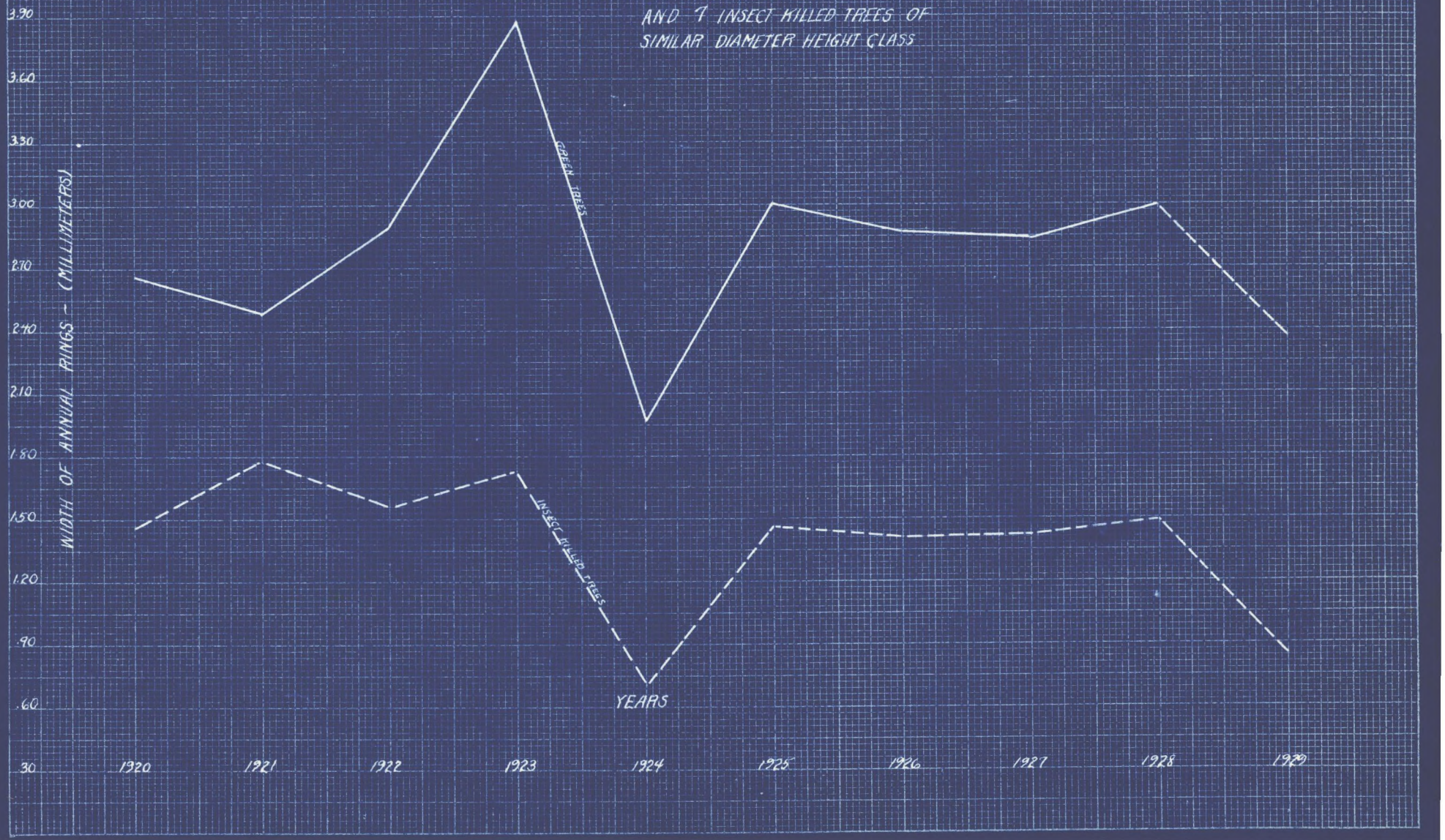
WATER TANK SELECTION PLOT
COMPARATIVE GROWTH RATE OF
25 GREEN AND 25 INSECT KILLED
TREES HAVING SIMILAR D.B.H. AND HEIGHT



U. S. GOVERNMENT PRINTING OFFICE: 1933 S—6345

FIGURE 7

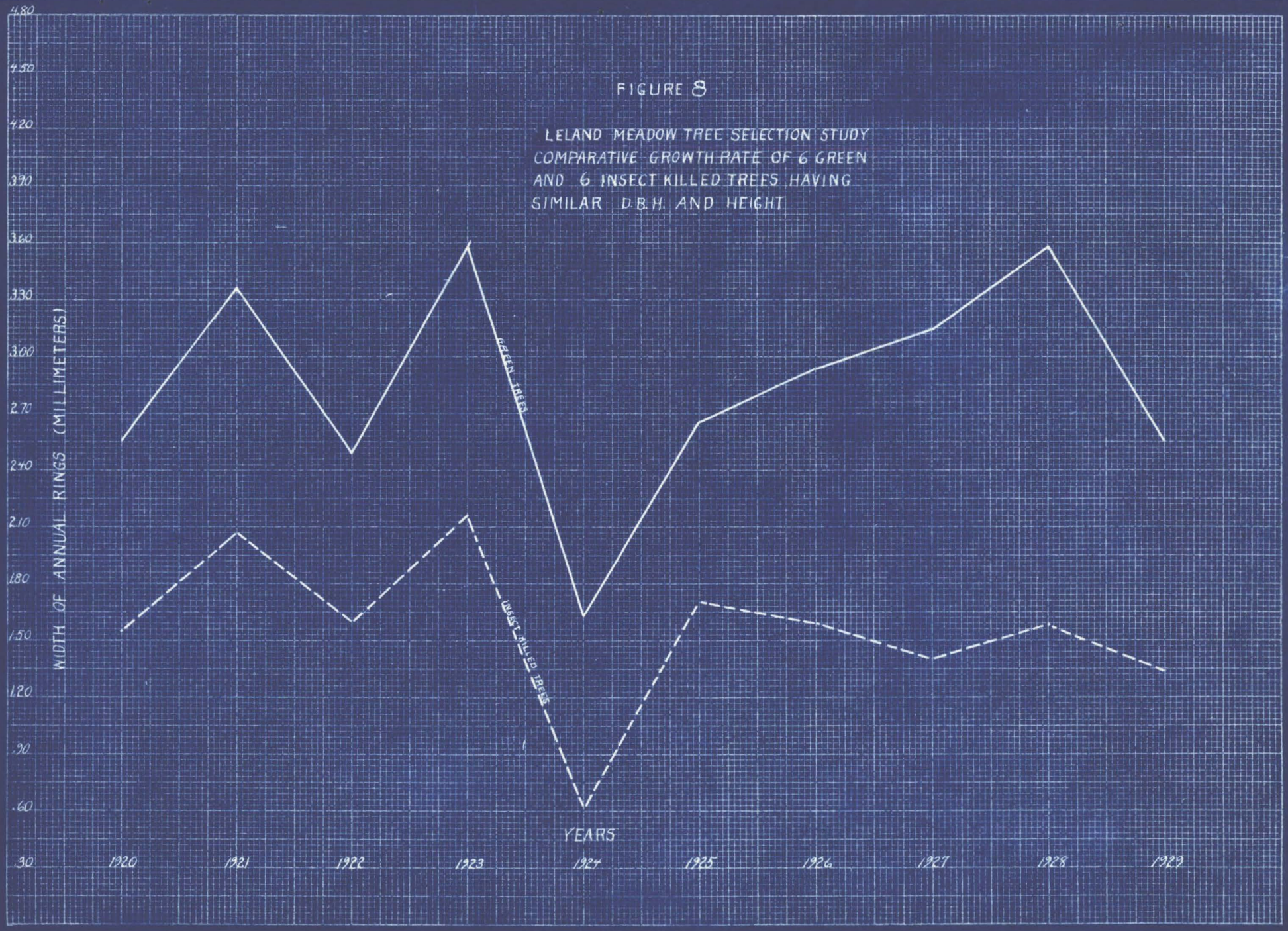
COLD SPRINGS TREE SELECTION STUDY
AVERAGE GROWTH RATE OF 7 GREEN
AND 7 INSECT KILLED TREES OF
SIMILAR DIAMETER HEIGHT CLASS



U. S. GOVERNMENT PRINTING OFFICE: 1928 8—6348

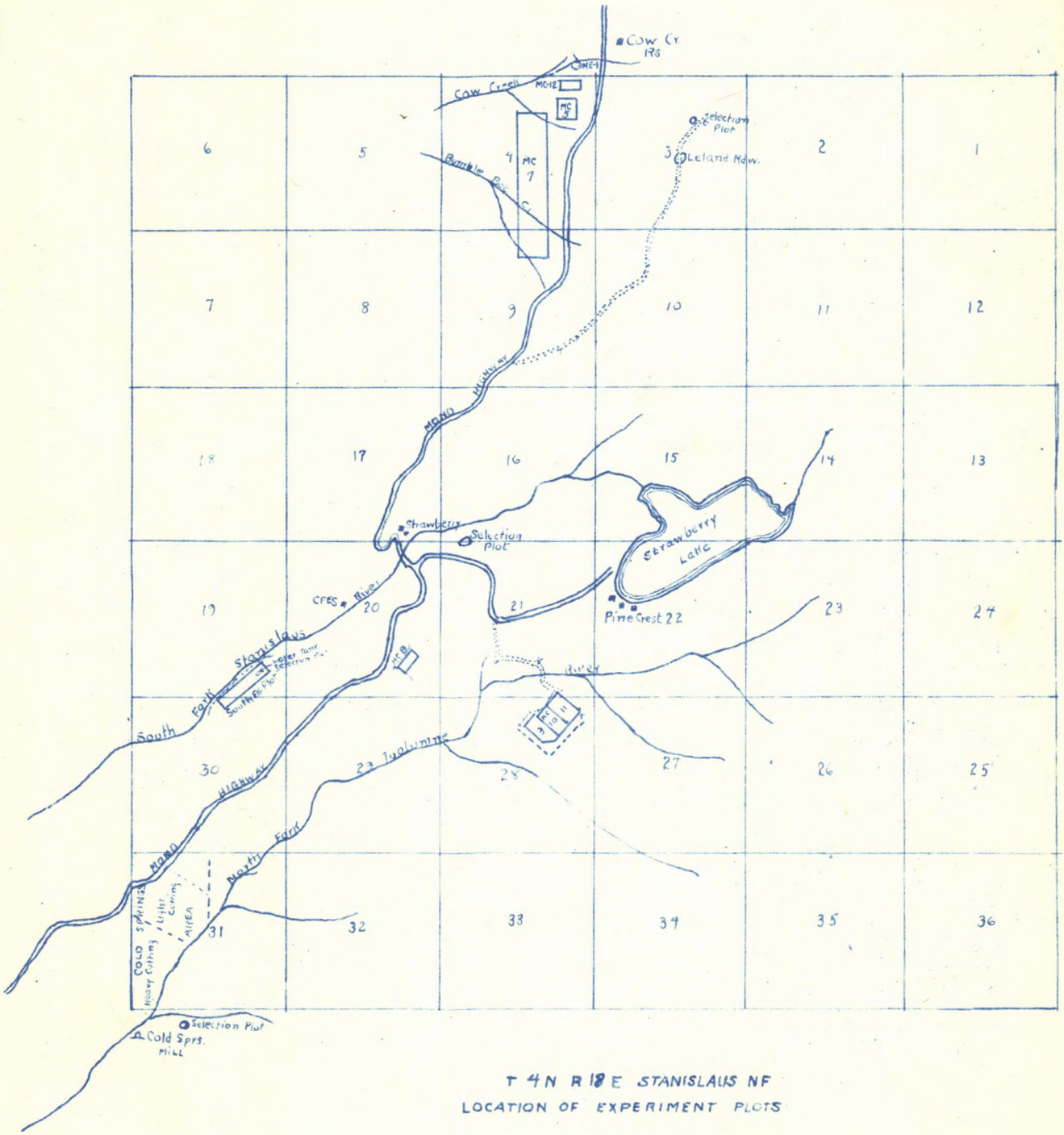
FIGURE 8

LELAND MEADOW TREE SELECTION STUDY
COMPARATIVE GROWTH RATE OF 6 GREEN AND 6 INSECT KILLED TREES HAVING SIMILAR D.B.H. AND HEIGHT



U. S. GOVERNMENT PRINTING OFFICE: 1933 S—6348

FIGURE 9



T 4N R 18E STANISLAUS NF

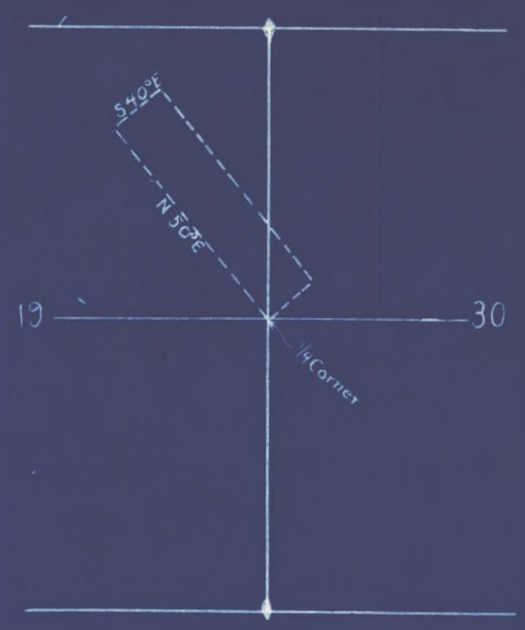
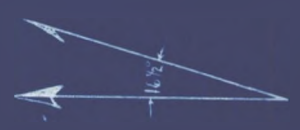
LOCATION OF EXPERIMENT PLOTS

FIGURE 10

SOUTH FORK CHECK AREA

SCALE 1" = 2½ CHAINS
T4N; R18E; S19 & 30 (PARTS)

LEGEND

Railroad.....
Railroad Cut.....
Rock outcroppings.....
Streams.....
Intermittant streams...
Logging boundaries.....
White fir.....WF
Sugar pine.....SP
1929 trees.....
1930 trees.....
Top killed trees.....
1928 trees.....

Cruised 8/26/30
Spotter Geo. R. Struble
Compass and Map-P.C.Johnson